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# THE SHOCK AND VIBRATION DIGEST. Volume 13. Number 8,

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WASHINGTON, D.C.

Judith Nagle-Eshlemen

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# THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 8
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A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

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# SVIC NOTES

## SPECIFICATION OF PYROTECHNIC SHOCK TESTS

Pyrotechnic shock continues to be a problem for designing and testing aerospace equipment. It is a problem because the outcome of the tests are too method-dependent. This is true because the damage potential of a shock pulse can vary with the pulse characteristic even though the pulses have the same shock response spectrum. Some individuals have reported a factor of 10 difference in the response of an internal item to two test methods, even though the shock response spectrum was the same. Because of this discrepancy, some equipment has been overtested and other equipment has been isolated when it should not have been.

How can this be true? What is there about specifying a pyrotechnic shock test by a shock response spectrum alone that allows for so much variability in the test results? The answer is in a single word - simulation! The pyro-shock tests that have best simulated the in-service conditions have been the ones that caused the same failures found during actual usage. Putting it another way, the pulses have the same damage potential. There are several reasons why this is true.

Part of the problem lies in the limitations of the environmental test laboratory. Most laboratories can do shock testing with drop tables, hammer blow machines or maybe even shakers, but they are not certified to do live explosive testing. They find that it is too costly to build their own explosive facility, or too difficult to find an available commercial facility close by. Therefore they did the best they could with what was available. Another important reason why these tests have been done with mechanical/electrical devices rather than explosives is that it is comparatively easy to raise the test level using non-explosive methods. It is a simple matter to raise a hammer a few more inches or to dial in a higher shock level on a shaker.

There are several reasons why test machines do not generate shocks with the same damage potential as explosives. In a live pyro event, there are both positive and negative high-g, high-frequency stress waves which propagate out from the pyro device. The stress waves arrive at the mounting points of equipment at varying times, with different phases and with both x, y and z components. On a shaker or hammer-blow machine the shock is put into all mounting points simultaneously in one direction. This in itself may cause an overtest. The impedance of the fixture on a shock machine or shaker usually does not resemble the impedance on an item in service. The fixtures are usually far more massive and rigid.

Another problem is the frequency content of the shock spectrum. A shaker will often have poor high frequency content and a drop table or impact device will have too much low frequency content. Since many test specifications allow an envelope around the 'desired' specification, a shock spectrum can be squeezed into an envelope where the actual test levels are too high at one end and too low at the other! Again the shock will not have the same damage potential.

A method has been developed which eliminates most of the above-mentioned problems. This method requires the building of a simulated structure with a built-in anvil. A rod is attached to the anvil such that a cylindrical weight slides down the rod to impact the anvil. The advantages of this method are that the frequency content, phasing and transient nature of the pulse are well simulated. The impedance of the mounting points are correct and the shock levels can be increased by simply raising the weight a few inches.

It seems to me that environmental test engineers should become more aware of the damage potential inherent in the various test methods and choose the method which will cause the correct failure modes in their equipment. The specification writers should also increase their knowledge of the limitations inherent in the available test methods so they will be able to write more realistic test specifications and be in a position to better monitor test results. The problems associated with pyrotechnic shock testing are still with us. If we continue to use the shock response spectrum alone to specify a test without any reference to the method used, we will continue to have varying failure rates from the test.

J.G.S.

# EDITORS RATTLE SPACE

## THE PUBLISHING GAME

Those of you who read this column probably remember my lengthy commentaries about the growing number of publications on shock and vibration technology. A recent editorial published in **Science** magazine* titled "The Publishing Game: Getting More for Less" indicates that engineers have a long way to go. They are just beginning to approach the sophistication of researchers in the life sciences insofar as "paper inflation" is concerned. This editorial was critical of fragmentation of research findings, coauthorship, and duplicate publication. The fact that some researchers in the life sciences can list as many as 700 papers in their curriculum vitae is justification for criticism.

The publish or perish mania has led to the emergence of the Least Publishable Unit (LPU) -- a term associated with the fragmentation of data and techniques. For instance an author might divide an article on a subject into a series of articles -- each containing enough information to justify publication. Unfortunately the practice not only leads to diffusion of information but also results in duplication of background material and references and replication of the reported research material. Publication costs have forced many publishers to demand word limitations on manuscripts. Instead of well written condensations of data and descriptive material, however, editors are now receiving fragmented information -- i.e., the LPU. This practice, admittedly difficult to deal with, could be controlled by extensive review and editorial work.

Another major concern of the **Science** editorial was coauthorship. In a study conducted by the Institute of Scientific Information, which indexes 2800 journals, the average number of authors per paper rose from 1.67 to 2.58 between 1960 and 1980. Coauthorship in the engineering field does not seem to have increased at this rate, however; perhaps engineers are not as dependent for advancement on numbers of papers as are individuals in other disciplines. The last criticism in the editorial had to do with duplicate publication and publication of preliminary results, extended results, and more-or-less-detailed results in different forms and media.

In my opinion, the abuses enumerated in **Science** could be rectified by good reviewers and editors. Unfortunately too much time would be required to research the background of each manuscript offered for publication. As one of the organizers for a recent meeting, I found reviewers extremely difficult to obtain. Certainly it is time consuming work that is uncompensated and unrecognized. However, in general, our publications will be no better than the quality of the review process. Perhaps we need to find a way to recognize reviewers.

R.L.E.

** Science, Vol. 211, 13 March 1981, p 1137.*

# BIODYNAMIC RESPONSE TO WHOLE-BODY VIBRATION

**M.J. Griffin***

***Abstract.** Recent experimental studies of biodynamic response to vibration and some attempts to model this response are reviewed. It is proposed that biodynamic models should be classified according to their general application. It is shown that the responses of the body to vibration are highly varied and that there is a need for increased availability of experimental biodynamic data.*

Biodynamics is a broad subject ranging from purely experimental to entirely mathematical studies of body motion. The last five years have seen the publication of new information on both measures and predictions of the mechanical impedances, transmissibilities, and gross movements of the whole body and of body parts. In addition, new mathematical models and revisions of earlier models have been defined to predict bodily injury and human performance.

Although the collection and manipulation of biodynamic data is often seen as an objective, the prime justification for biodynamic studies remains minimization of the effects of vibration and impact on human comfort, performance, and health. A review of recent developments reveals that the complexity of body dynamics is now widely accepted; in some cases advanced models have been devised to describe this complexity. However, parallel efforts to advance experimental work are also required to assist both the evolution and the evaluation of such models. Further, without experimental and epidemiological studies of the effects of vibration on comfort, performance, and health it is not known which parameters of vibration should be used with the biodynamic models (or measures) to minimize discomfort, loss of performance, and injury or disease.

This review concentrates on biodynamic research as it affects body movement due to vibration. The physiological and psychological effects of this movement on responses to high levels of impact are not considered. (Some recent advances in the field of impact modeling are included in two conference proceedings [1, 2].) The prime measures under consideration are therefore transmissibility (usually the ratio of motion at some point on the body to motion at the interface between the body and the vibration source) and mechanical impedance (usually the ratio of force to velocity at the interface between the body and the vibration source).

## EXPERIMENTAL STUDIES

Although variability and adaptability to vibration among and within individuals are of paramount importance, they have often been considered nuisances or sources of error rather than parameters requiring measurement. It has been reported that for some conditions intersubject variability in seat-to-head transmissibility is well approximated by normal distributions and that, although transmissibility is correlated with physical characteristics of subjects, the correlation is probably insufficient t· be of practical value [3]. Sex and age also have statistically significant, although small, effects on seat-to-head transmissibility [4].

It has been shown that the type of backrest on a seat can affect the level of vibration reaching the head [4-6] and that the effect is dependent on the axis of vibration of the seat [7]. At low frequencies backrests can reduce head vibration levels. Alterations to head position [4] and even foot position [5] can also affect head motion when a seated person is exposed to vertical seat vibration.

Body posture, muscle tension, and body restraints have long been reported to affect head motion. Mean changes of 600 percent in vertical head motion due

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to posture changes with vertical seat vibration have been reported [8]; see also Figure 1. Although such changes correspond to extremes of posture, they indicate the type of effect that occurs with more typical changes from a slumped to a sitting position. It has been shown that subjects adopting normal upright postures generally have transmissibilities in the range defined by stiff and relaxed postures [4]. At frequencies above 5 Hz stiff postures cause more head motion; the converse is true at lower frequencies.

It appears that, although any nonlinear effects in response to vibration alone might be due to voluntary postural changes [4, 8], larger and more predictable changes in vibration transmissibility occur with changing levels of sustained acceleration [9, 10]. Some attempts have been made to investigate the importance of the experimental method used to determine seat-to-head transmissibility. Comparative measures using discrete sine and various swept sine and random motions in combination with transmissibility calculations using such methods as root mean square, power spectral density, and cross-spectral density often show only small differences due to the choice of method [4].

Data from studies of vision during vibration show the rotational head vibration caused by rotational oscillation of the body [11, 12]. Studies have quantified the rotational head vibrations caused by translational seat vibration [7, 8, 13]; see Figure 2. Other data reflect the transmission of vibration from head to eye [14-20] but contain conflicting conclusions on the existence of eyeball resonances.

For a seated person the degree to which vibration is transmitted to the hand is a dominant factor in

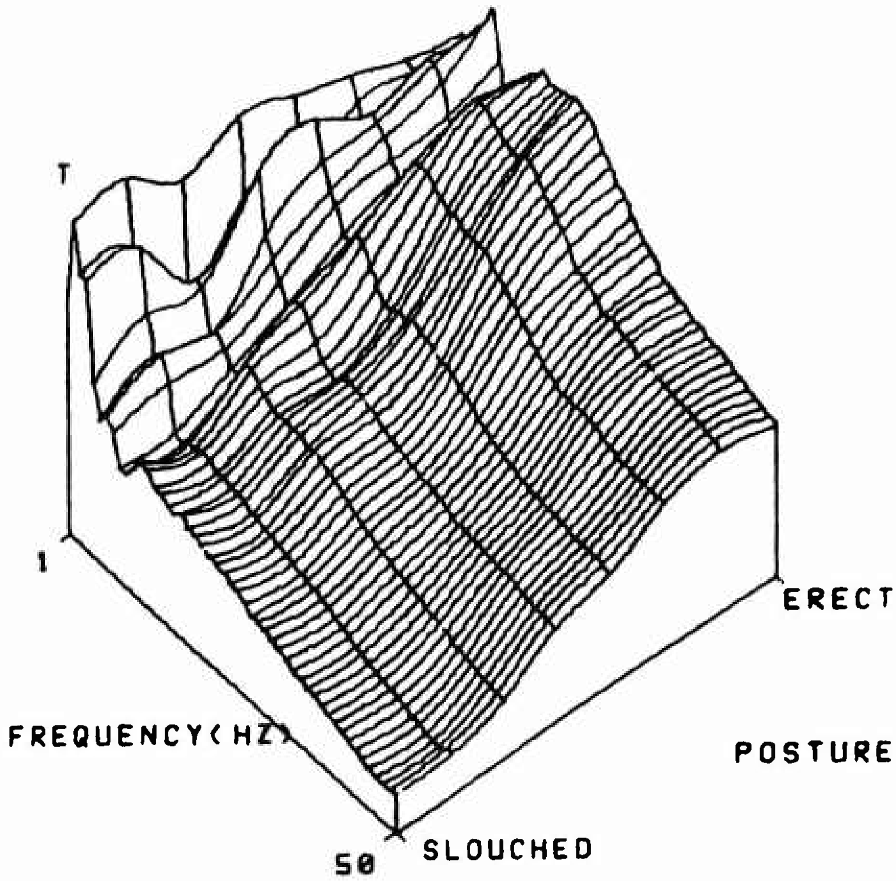



**Figure 1. The Seat-to-Head Translational Vibration Transmissibility from 1 to 50 Hz of a Single Subject Sitting in 8 Postures from Slouched to Erect [4]**

determining the effect of vibration on control tasks involving the hands. With continuous control tasks this vibration, often called feedthrough or breakthrough, produces a component in the tracking error record that is often the principal error component. The transmission of vibration from seat to shoulder and hand has been reported [21, 22]. Both the levels of vibration at the hand and their significance are system-dependent and vary according to such factors as control dynamics.

The transmission of high levels of vibration to the hand from hand-held tools can cause injury -- most notably Vibration-induced White Finger or Raynaud's phenomenon of occupational origin. This injury has stimulated various studies of the mechanical impedance of the hand-arm system [23, 24], the transmission of vibration to the hand and arm [25, 26], and the measurement of energy absorbed by the hand [23, 24, 27-29]. It has been shown that the point impedance of the hand is dependent on arm position, grip, push force, and the axis of vibration [23, 24, 30]. Various models of the hand-arm system have been devised [23, 24, 31-33].

## MODELS OF BIODYNAMIC RESPONSE

Biodynamic models might be devised for a variety of purposes. For example:

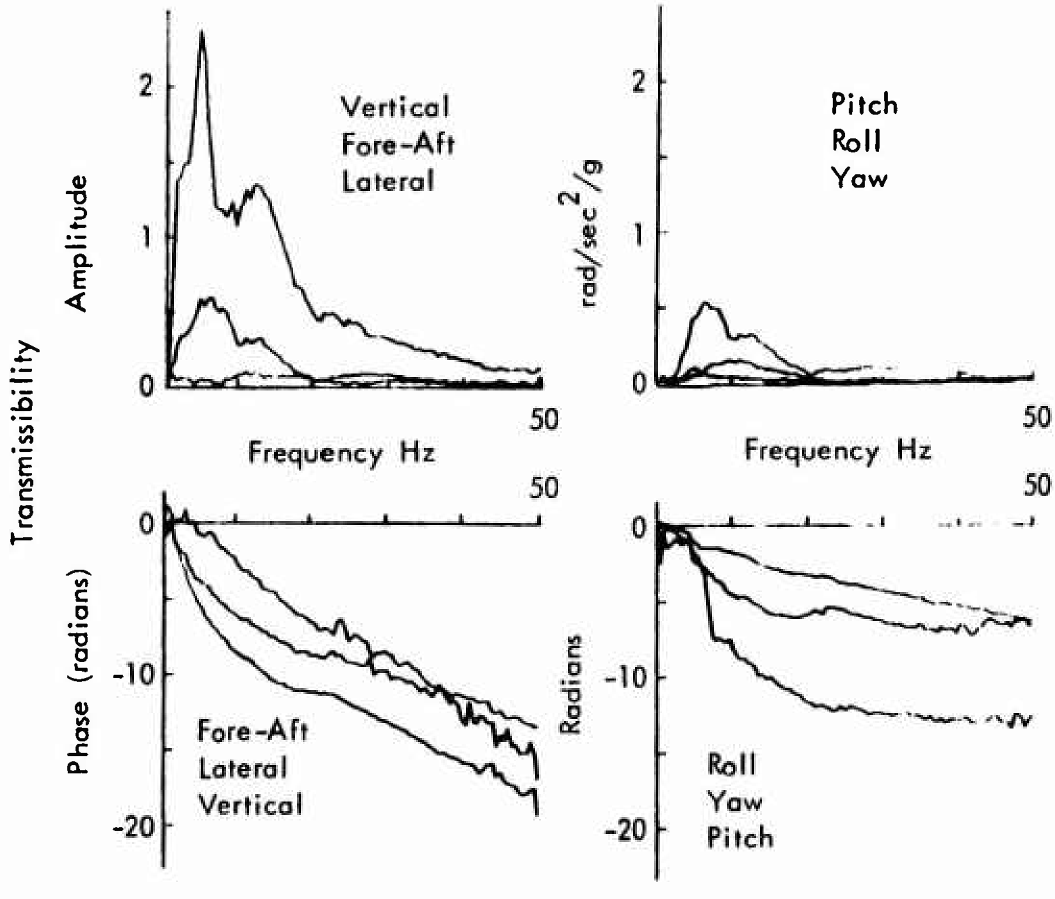



**Figure 2. Transfer Functions (Modulus and Phase) between Vertical (z-axis) Seat Vibration and Translational (Fore-and-Aft, Lateral and Vertical) and Rotational (Roll, Pitch and Yaw) Head Motion. (Previously Unpublished Data from One Subject Using a Hard Flat Seat without Backrest and Measuring Head Motion with a Bite-bar)**

Type (i). To predict movement or forces caused by situations too hazardous for an experimental determination

Type (ii). To predict movement or forces caused by situations too numerous and varied for experimental determination

Type (iii). To understand the nature of body movements

Type (iv). To provide information necessary for the optimization of isolation systems and the dynamics of other systems coupled to the body

Type (v). To determine standard impedance conditions for the vibration testing of systems used by man

Type (vi). To provide a convenient method of summarizing average experimental biodynamic data

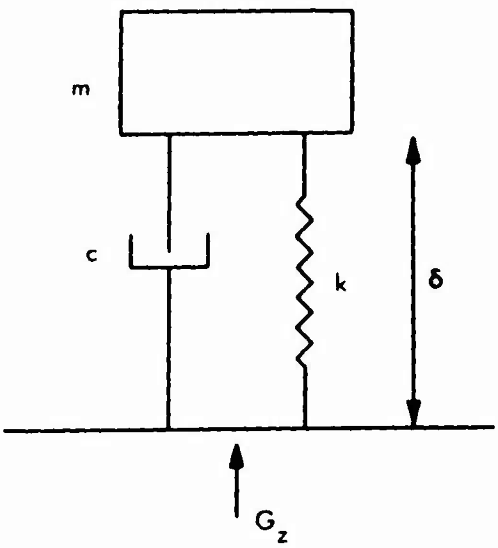
Type (vii). To define variables affecting biodynamic response

All current models of the dynamics of the human body are highly restrictive in their application. They are often a Type (vi) model proposed for use as a Type (i), (ii), (iii), (iv) or (v) model. Models are commonly based on point impedance data and apply to single axis translational vibration normal to the point of contact.

One of the simplest and most used models in recent years is that employed in the Dynamic Response Index (DRI). The DRI model was originally evolved in connection with the study of acceleration in the headward direction from aircraft ejection seats. It is a single-degree-of-freedom lumped parameter model as shown in Figure 3. The damping ratio is 0.224, and the natural frequency ($\omega_n$) is 52.9 rad/sec. The Dynamic Response Index is defined as $\omega_n^2\ \delta max/g$, where $\delta_{max}$ is the maximum deflection and g is 9.81 $m/s^2$. An approximate relationship between DRI values and the probability of spinal injury has been established.

In the last few years it has been proposed that the DRI should be extended to repeated shocks (from 1 to 20,000 shocks per day) so as to fill the gap between single events and continuous vibration [34]. It has also been suggested that the DRI, representing a spinal model ($\omega$ = 52.9 $\bar{c}$ = 0.224), should be supplemented by a visceral model ($\omega$ = 25.1 $\bar{c}$ = 0.4) and a body vibration model ($\omega$ = 52.9 $\bar{c}$ = 1.0); see Figure 4. A low frequency (motion sickness) model ($\omega$ = 1.571 $\bar{c}$ = 1.0) has also been proposed. The maximum rms acceleration output from these four single-degree-of-freedom systems would then be used to calculate a total Vibration Ride Quality Index [35].

A more complex model than that used for the DRI has nonlinear characteristics [9, 10]; see Figure 5. It has been suggested that this nonlinear model is more appropriate when the injury potential of extreme shocks is assessed and the response of the body




Natural Frequency $= \omega_n = \sqrt{\frac{k}{m}} = 52.9$ rad/s

Damping Ratio $= \zeta = \frac{c}{2\sqrt{km}} = 0.224$

D.R.I. $= \omega_n^2\ \delta_{max} / g$

(where $\delta_{max}$ = max. deflection)

Figure 3. The Model Used for the Dynamic Response Index

to combined vibration and steady-state acceleration is predicted. A very different lumped parameter model containing frequency-dependent damping coefficients was earlier defined by Muksian and Nash [36].

The use of absorbed power for predicting discomfort due to whole-body vibration has been proposed over many years [37]. The combined use of absorbed power, a so-called Amplitude Frequency Distribution (AFD) method, and a mechanical model with representative response has also been proposed [38].

An International Standard [39] soon to be published will define the standard mechanical impedance of man in three positions: sitting, standing, and lying (see Figure 6). The modulus and phase of mechanical impedance predicted by three different models corresponding to the three different postures are compared with some experimental data. The experimental data used to derive parts of the standard are sparse, and doubts exist concerning the limits of application of these data. For example, it is not known how the presence of a backrest modifies the impedance of a seated person; nevertheless, the standard serves to emphasize that the body cannot be considered a rigid mass at frequencies above

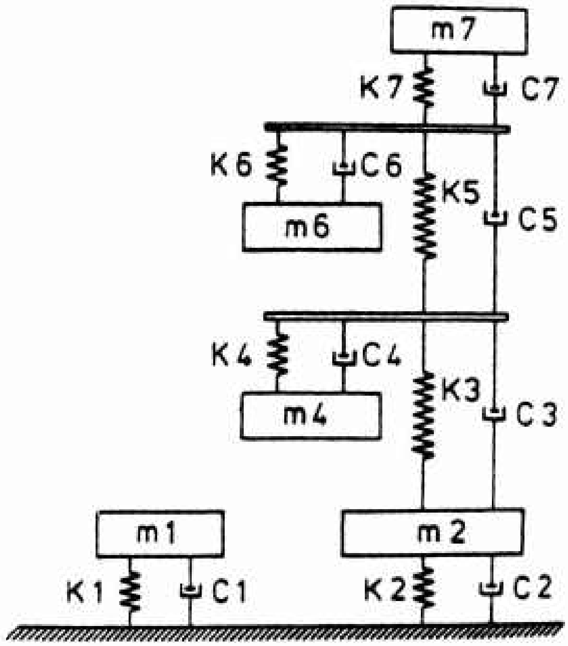



Figure 5. Multi-Degree-of-Freedom Nonlinear Model of the Sitting Human Body [9, 10]

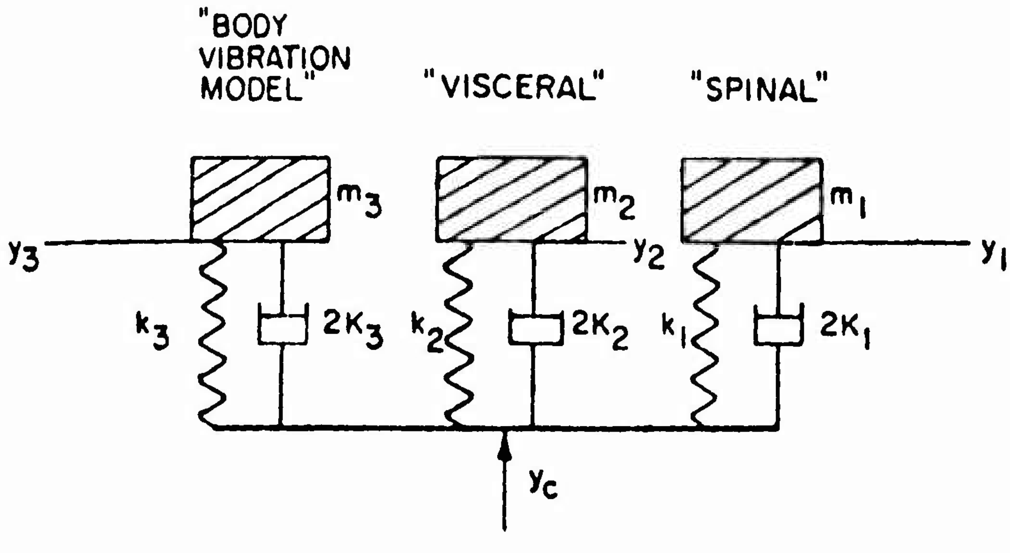



Figure 4. Ride Quality Model Proposed by Payne [35]

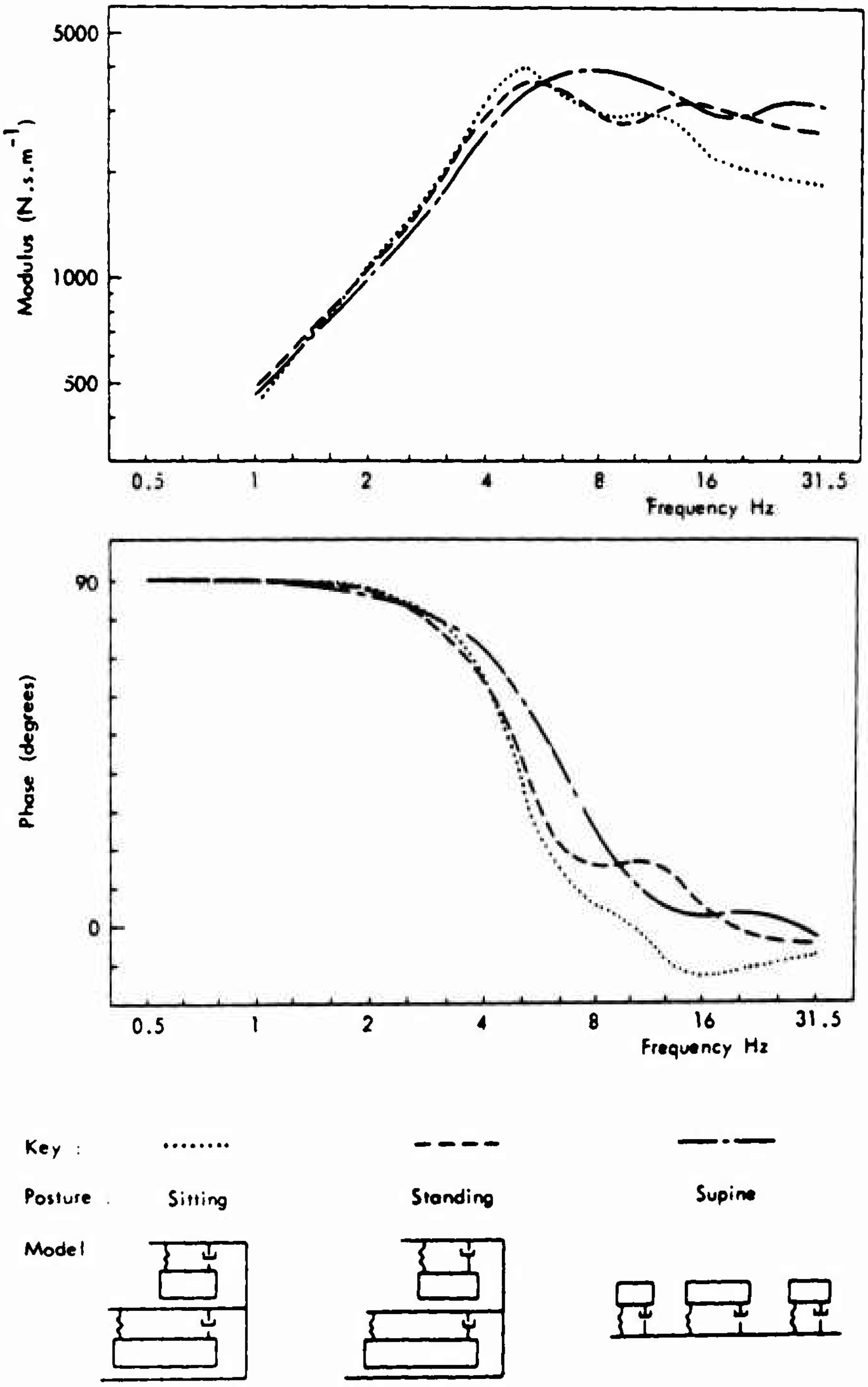



Figure 6. Mechanical Driving Point Impedance of the Human Body in Three Postures as Defined in International Standard 5982 [39]

about 4 Hz and might stimulate further investigations and a greater understanding of whole-body mechanical impedance.

A few complex models have been evolved specifically to predict the effects of whole-body vibration on human performance [40, 41]. Such models tend to be complex because it is necessary to predict both the movements of several body parts (e.g., hands and eyes) and the effect of these movements on performance. The models are further complicated by the need to allow for variable postures and control/display locations and characteristics. Such systems are already valuable as Type (vii) models and, with care, might be usable as Type (ii) models for investigating the importance of posture and position and Type (iv) models for considering optimum control dynamics. It remains to be seen whether the extreme complexity of a fully comprehensive model of this type is a practical means for summarizing experimental data as for a Type (vi) model.

A considerable number of other biodynamic modeling exercises have been conducted -- most of which are oriented toward predicting injury due to impact. However, the concepts, methods, or results of several studies have possible applications to vibration and repeated shock. For example, a spinal model has been defined and its responses compared with those measured in cadavers [42, 43]. Some impact measurements recorded from human subjects have been compared with those predicted by three of the more commonly available computer programs used to estimate body responses in crash situations [44, 45]. A three-dimensional head-spine model has also been evolved [46, 47]. This model is intended for applications similar to pilot ejection from aircraft but has been influenced by studies of biodynamic response to vibration.

## CONCLUSIONS

It has been suggested that models of biodynamic response to vibration might be required for at least seven different general purposes. The form and sophistication required of a model depend on both its general purpose and its specific application. A Type (vi) model might be radically different from a Type (ii) model -- even though they are based on the same data. A model for predicting spinal injury might have little in common with a performance model. A model for horizontal vibration might be entirely different from one for vertical vibration. The range of possibilities is probably too great for any single, practical, unifying model.

In practice, the extent of human variability and the shortage of experimental data often make it possible for simple models, such as the single-degree-of-freedom system used for the dynamic response index, to compete successfully with the most complex model. The advantages and disadvantages of increasing the complexity of models are insufficiently clear to conclude the degree of sophistication required.

A more important current problem surrounds the relation between the biodynamic theoretician and the empiricist. Published experimental data on human biodynamic responses leave much to be desired. Models must often be based upon, and validated by, experimental data that are clearly inadequate. One commonly neglected group of problems are associated with individual variability. Is it better, for example, to consider the biodynamic data from one subject, the mean data from four subjects, or the mean data from forty subjects? Although the answer is important, the question does not arise when only one set of suitable data is thought to be available. It is therefore important that experimental data are made more readily available. This must happen before the principal objective of some modeling studies -- i.e., elimination of the need to experimentally expose man to vibration -- can be declared to have been fulfilled!

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# LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles inlcude technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about the role of similitude in fatigue and fatigue crack growth analyses.

Dr. B.N. Leis and Dr. D. Broek of Battelle, Columbus Laboratories, Columbus, Ohio have written a paper considering the role of similitude between damage states being compared during fatigue crack initiation and propagation analyses based on laboratory specimen tests. The review focuses on developments during the last several years pertinent to ensuring similitude in damage processes.

# THE ROLE OF SIMILITUDE IN FATIGUE AND FATIGUE CRACK GROWTH ANALYSES

B.N. Leis and D. Broek*

*Abstract. The paper considers the role of similitude between damage states being compared during fatigue crack initiation and propagation analyses based on laboratory specimen tests. The review focuses on developments during the last several years pertinent to ensuring similitude in damage processes. It begins with a review of the technology to the present in terms of measures of damage, crack nucleation, crack growth, and the marriage of nucleation and growth analysis. Developments pertinent to these topics based on the past several years are elaborated and reference is made to multiaxial, thermal, and environmental effects. A commentary then considers these developments with a view to future directions. It is concluded that, when care is taken to ensure similitude at critical locations such as notch roots and crack tips, accurate predictions can be made of structural fatigue resistance based on laboratory test data. Four areas of future research are identified as significant if this conclusion is to be considered general: crack initiation and growth in gradient fields, inelastic analyses, thermal and environmental effects, and multiaxial aspects.*

## BACKGROUND

The purpose of this review is to examine developments in fatigue analysis during the last several years. Fatigue analysis is taken herein to mean analysis of the damage resulting from the coupled action of at least a local tensile stress and reversed (microscopic) plastic strain. Damage is defined as progressive degradation of the strength and serviceability of a structure associated with fatigue crack nucleation and stable growth until the residual strength of the structure is reached. The review does not address such failure modes as cyclic instability (incremental collapse) and shake-down, brittle (dynamic) fracture and residual strength analysis, and wear related mechanisms. Multiaxial action, elevated temperature, and environmental aspects are considered briefly.

This review is particularly concerned with the analysis of nucleation and growth of fatigue cracks for purposes of assessing fatigue resistance in situations in which extensive verification testing during product development is precluded. Fatigue analysis fits into the overall scheme of product development as shown in Figure 1. Figure 1A indicates that such analysis follows basic structural analysis, in which, as illustrated in Figure 1B, geometry, material properties, and loads are transformed into data useful in assessing strength, serviceability, and stability. Life prediction is a post processor of these data as shown in Figure 1C. Data from the stress analysis are mapped into damage increments that are integrated over some presumed loading history until failure is indicated.

It is desirable to develop accurate analysis schemes that minimize the number and scope of fixes identified through a full scale test and to use only simple materials test data and the results of appropriate stress analyses. However, the damage process in test samples can differ significantly from that in a structure when simple materials data (simple cyclic loads and test geometries) are used. The fundamental tacit assumption is that damage processes being compared in the analysis are or can be considered identical. It is thus necessary to ensure that reference laboratory test data reflect the significant damage mechanisms and factors that control the damage rate in the structure; i.e., the damage processes must be similar.

The review begins with a consideration of the technology to the present in terms of measures of damage, crack nucleation, crack growth, and the marriage of nucleation and growth analysis. Developments pertinent to these topics during the past several years are elaborated, including multiaxial, thermal, and environmental effects. A commentary considers these developments with a view to future directions.

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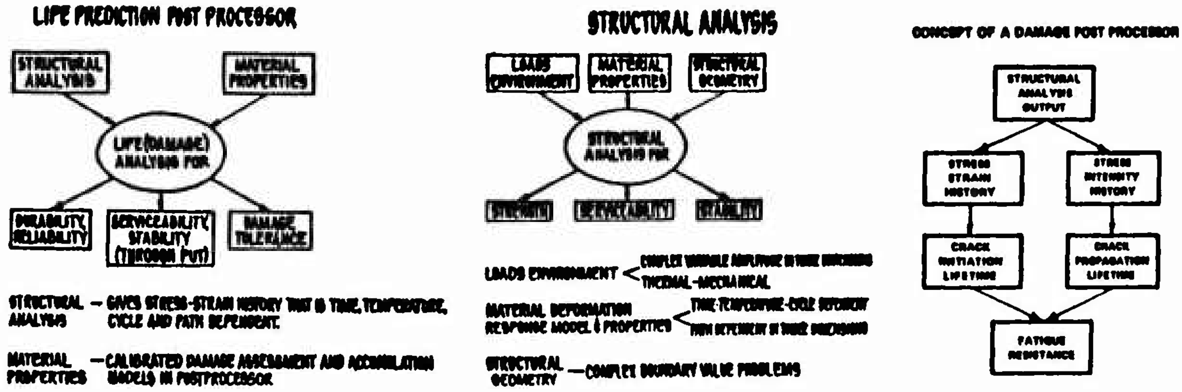


Figure 1. Interactions among Fatigue, Fatigue Crack Propagation Analysis, and Structural Analysis

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***Phenomenology of damage.*** The fatigue damage process can be considered to occur in the uniform section of a low cycle fatigue (LCF) test specimen or at a crack tip. That is, an element of material suffering fatigue damage does not know if it is in a smooth LCF specimen at a notch root, or at a crack tip. The damage rate varies, however, depending on geometry and the location of the element within the specimen. Several authors have presented such microstructural evidence. Laird [1] has indicated that the mechanical response of an LCF specimen is a macroscopic measure of the reversed plasticity damage process that leads to nucleation (e.g., formation of persistent slip bands). Such variables as stress and strain, which reflect mechanical response, can thus serve as measures of reversed slip damage during nucleation. Neumann [2] and Broek [3] have indicated that the stable growth of nucleated cracks is a geometric consequence of slip. During crack growth, therefore, measures of the propensity to slip -- near crack tip stress and strain -- or the extent of slip -- changes in crack tip geometry or position -- can serve as near-crack tip measures of the crack growth process.

Figure 2 shows this reversed plasticity damage process: in the bulk -- nucleation, and then at a crack tip -- macrocrack propagation. The nucleation process often dominates the fatigue behavior of the cylindrical smooth (CS) sample. By way of contrast, the propagation process dominates the total life of the compact tension (CT) geometry often used to develop fatigue crack propagation (FCP) data. What is missed in the schematic in Figure 2 during the transition from nucleation, through for example, persistent slip band formation to stable macrocrack growth, is the microcrack growth domain.

As shown in the schematic of Figure 3, microcrack growth can be lumped into the so-called continuum stage of the damage process. This stage represents the essential difference between damage that develops from a free surface and that which develops from some naturally occurring or processing/fabrication-induced crack-like defect. Note that the fatigue damage process can span about 10 orders of magnitude in the damage scale. For cracks that may be present at the structural level, the rate of crack growth is a popular measure of damage rate. At the other extreme are defects on the order of atomic distances. If such defects were like cracks, the rate of growth of microstructural discontinuities could be used as a measure of damage rate. But growth rates of such defects through ten orders of magnitude have not yet been characterized by a single internally consistent physical or mathematical model. Consequently, the concept of stages and models for each has become popular.

The concept of stages has led to difficulties in making accurate life predictions. One reason has to do with the specimen geometries used to develop the data used in calibrating mathematical models of the nucleation and growth damage processes; the CS specimen emphasizes but does not isolate the nucleation stage. Unless the damage rate process being represented by that specimen embodies the same

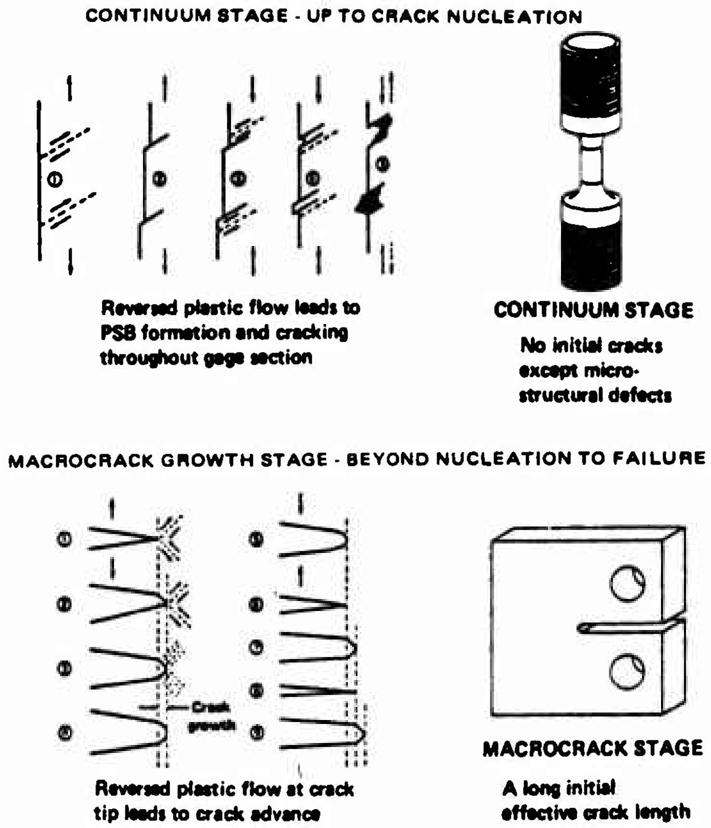


Figure 2. The Development of Fatigue Damage through the Continuum State into the Macrocrack State

mix of nucleation and propagation damage as the CS specimen, the damage rate processes will be dissimilar. Another reason is that damage rate is not necessarily a unique function of the parameter used to measure damage; that is, the parameter is an inadequate measure of damage rate. Each difficulty will be elaborated following a discussion of measures of damage rate.

***Measures of damage.*** From the work of Wood [4] and Forsythe [5] it is clear that the macromechanics of damage for each of the three stages shown in Figure 3 differ, even though reversed plasticity is common to each stage at the microscopic level. It is, therefore, not too surprising that such bulk measures of the damage process as stress and strain indicate substantially different damage accumulation rates between different stages. Indeed, it is such differences that gave rise to so-called double linear damage rules [6] when a single measure of the damage rate process was used to characterize more than one stage. Continuing in this vein one might consider a trilinear rule for the three stages shown in Figure 3. Unfortunately such an approach addresses the symptom and not the disease.

Mechanics analysis and a consistent measure of damage for each stage is required. A means for delineating stages of the damage process is then needed. It should be emphasized that this delineation is artificial in that both nucleation and growth share a common mechanism and, as such, could be represented in a single model. The delineation between stages, therefore, must be consistent with the physical nature of and the driving force for the damage rate process.

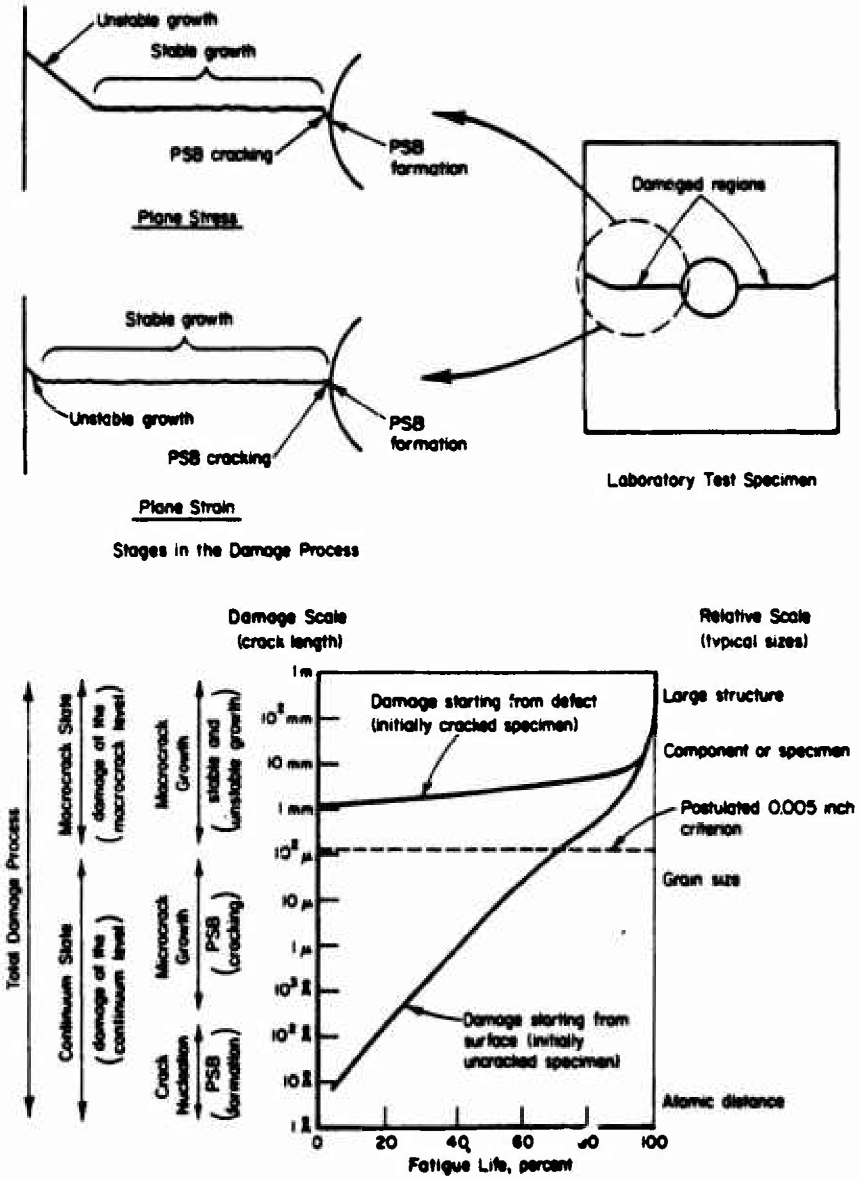


Figure 3. The Fatigue Damage Process

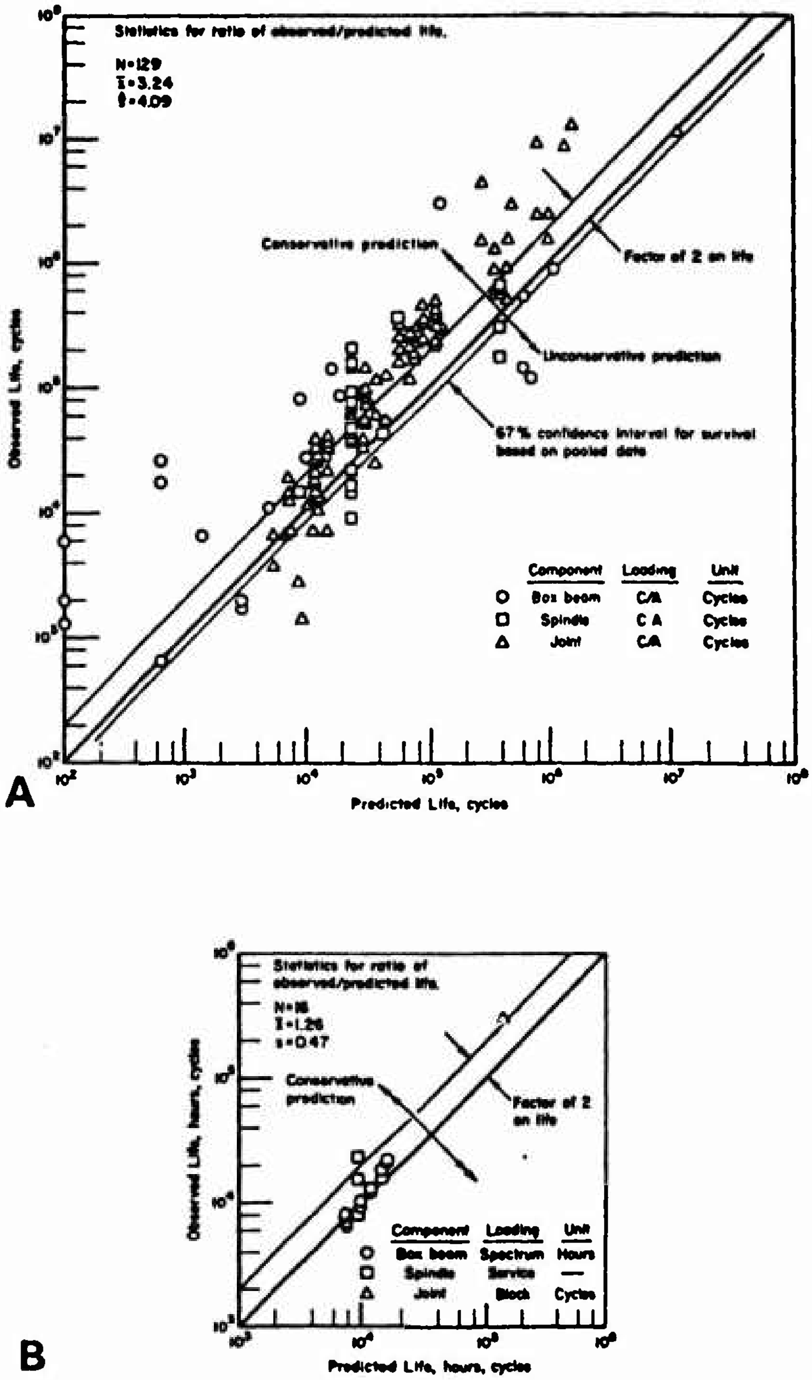


Figure 4. Comparison of Predicted and Observed Fatigue Resistances for Components [69]

This in turn means that the delineation must evolve from the mathematical models for nucleation and growth. In an engineering sense the error associated with the implementation of the demarcation must be small. That is, damage analyses for the nucleation stage must not admit a significant period of crack growth. Consistency requires that analysis of crack growth behavior must continue the development of the nucleated crack.

It is convenient to delineate the stages of the damage process in terms of two damage states (see Figure 3). In the first -- the continuum state -- such direct measures of damage as crack propagation are not reliable because of the scale at which damage occurs and the fact that, in a statistical sense, damage occurs in a large volume of material. Given these considerations the continuum state includes persistent slip band (PSB) formation and cracking*. At the end of the continuum state a microcrack on the order of $10^2$ $\mu$m is considered to have formed from the area of strain localization (defect sizes $\sim$ 1 to 10 $\mu$m). Cracks of this size are currently considered large enough to track. Consequently, beyond this domain crack growth rate is adopted as a measure of damage in the second damage state, called the macrocrack state. Crack growth rate is adopted as a direct measure of damage for the second state. It remains to define a damage measure for the continuum state. Such bulk measures as changes in stress and strain over some volume of material have traditionally been successfully used and are therefore adopted. Note that stress and strain can also serve as indirect measures of the macrocrack damage state, particularly such measures of the near tip stress-strain field as linear elastic stress intensity [7] range, $\Delta K$, or the J integral [8] range, $\Delta J$. Other measures of crack advance -- COD [9], CTOD [10], cracked area evolved -- can also be useful in place of crack tip advance.

***Damage parameters.*** It is now prudent to introduce the concept of a damage parameter. Recall that the fundamental assumption in damage analyses is that the damage rate at a critical location in a structure can be assessed in terms of the damage rate exhibited in some reference damage state. That is, if the driving force for damage in a given material is equal, equal increments of damage will occur. However, the variables controlling the damage rate process at a critical location in a complex structure can seldom be recreated in the laboratory. Mathematical expressions of these variables are therefore used to match the damage processes being compared; i.e., to ensure similitude.

Measures of the driving force of the damage rate process during each damage state that map the structural damage process into that occurring in the reference specimen are termed damage parameters. By definition, equal values of the damage parameter mean equal damage rates. In the continuum state total strain range $\Delta e^t$ serves as a damage parameter for fully reversed strain control cycling of many materials. In the macrocrack state, $\Delta K$ serves as a damage parameter under constant amplitude load control conditions at a given stress ratio.

***Marriage of nucleation and growth (continuum and macrocrack) analysis.*** When the damage parameter does not uniquely characterize the damage rate process, damage states are mismatched and damage increments are incorrectly computed. As noted earlier this is due in part to the traditional use of either CS, CT, or comparable specimens to characterize material fatigue and fracture resistance. Certainly both types of specimen embody the three stages of the damage process. However, these geometries are seldom used independently to develop data for all three stages. The CS specimen tends by design to emphasize the continuum state; the CT specimen lends itself to the macrocrack state. What is missed in this process is the study of the growth of microcracks 1 to 5 X $10^2$ $\mu$m long. Yet it is this regime of crack sizes that serves as the interface between analyses of crack nucleation and crack growth. Nor is this microcrack size dealt with directly by either nucleation or propagation analysis. As a result, matching the damage rate process in a structure with natural or fatigue initiated defects of this length is difficult.

## SIMILITUDE IN DAMAGE ANALYSIS

This section addresses the issue of mismatched damage states in the interface region and during nucleation and macrocrack growth.

***Nucleation (continuum state).*** Delineating the continuum and macrocrack damage states has been an open question for some time. A variety of constant crack lengths have been proposed for this purpose that range from about 10 $\mu$m to about 1 cm. Like-

****PSB formation is not essential to the concept of stages. The concept is valid so long as some form of localization of irreversible slip occurs.***

wise, several schemes that relate cycles to crack initiation to total life have also been suggested. In most cases the single crack length approaches have been advanced with a view toward implementing this demarcation in laboratory testing. As such, larger crack sizes have been suggested. Others, however, have given consideration to both the technical concern that to "match the damage rate processes at the tip of a crack at a notch root using reference smooth (CS) specimen data to a given level of accuracy, the maximum allowable crack length will decrease with decreasing notch root radius" [11] and the implementation problems. Using then available solutions for stress intensity at cracks in smooth and notched specimens, a very short length ($\sim 10^2$ $\mu$m) had been adopted [12]. Subsequently, this same problem was independently recognized and Dowling [13] using linear elastic fracture mechanics (LEFM) concepts developed an equation for expressing the transition from initiation to propagation as a function of root radius. At about the same time similar expressions were developed also using LEFM that established a notch equivalent crack length [14] as first suggested by Broek [15]. These expressions, which can be used in lieu of a fixed crack length to delineate continuum and macrocrack states, rely on LEFM and as such may be of limited value in applications to inelastically strained notch roots. For this reason, and because most data have been developed using a fixed crack length, such a criterion is used hereafter, the length being 125 $\mu$m. As such a crack is said to have initiated when it reaches a length of 125 $\mu$m.

Recent research into the role of similitude in making accurate life predictions has been extensive [12, 16-18]. These studies have been reviewed in detail elsewhere [19]. As such only the salient features are related here with the emphasis placed on the extent of the error that may result when similitude is not adequately achieved.

Achieving similitude requires that the damage processes being compared be matched by an appropriate damage parameter [20]. For nucleation such parameters embody stress and strain measures of damage. Predictions of structural life thus require an adequate means for computing stresses and strains at critical areas. Experience has shown that these computations must account for nonlinear material behavior that can occur at stress raisers in structures [11, 12]; that is, the method for determining the deformation state at the critical location must be known and adequately portrayed by the damage parameter. In addition, similitude requires that the reference data base must be matched to that of the structure. When structural life is predicted from smooth specimen data, therefore, some life associated with the formation of a small crack is also being predicted. If the smooth specimen data used to make this prediction embody significant fractions of both nucleation and growth, it becomes difficult to interpret what is being predicted in the structural context. That is, careful attention must be paid to the failure criterion.

Errors thus occur as a result of incorrect computation and representation of damage at stress raisers and are also associated with the failure criterion. Examples of the failure criterion have been reported in which different fractions of life are spent in nucleation and growth at different stress levels and at a given stress level [12]. The most significant recent examples pertain to cracks that nucleate but fail to grow. If an appropriate failure criterion is used, nucleation of such cracks could be predicted, but their nonpropagating character could not be [12]. Recent work by Miller [21] provides the basis for assessing whether such cracks will grow. But it should be emphasized that such predictions are limited to constant amplitude cycling situations.

The studies that have had to do with damage typically suggest that errors result from incorrect computation of critical location stresses and strains when the stress raiser is either inelasticaly strained [16, 18] or in a multiaxial field [22]. These errors can result in predicted lives that differ from corresponding experiments by as much as two orders of magnitude.

Other advances with regard to nucleation prediction have focused on verifying the use of the deformation theory of plasticity on a cycle by cycle basis. Experimental studies have now shown that, for a limited class of problems, the deformation theory, in conjunction with a few simple memory rules developed in stress strain space, can be generalized into force displacement space [23]. This in turn has led to the development of computer-based models that can be used to predict structural fatigue resistance under actual service loadings [24]. These highly efficient codes make use of the same basic logic to control cyclic stress-strain hysteresis calculations at the

structural and material levels as well as damage calculations. Such models yield accurate predictions for actual hardware subjected to a service load history (see Figure 4).

***Macrocrack growth.*** Macrocrack propagation remains an area of active research interest. Research in macrocrack growth modeling based on LEFM has continued as a consequence of difficulties encountered when it is applied to practical problems. Research focuses on four areas: development of stress intensity solutions, development of mathematical models of FCP under variable amplitude loading, FCP near the threshold, and FCP near limit load/fracture conditions.

With regard to stress intensity solutions, efforts have been concentrated on the usual analysis for specific geometries and on three-dimensional analysis for curved crack fronts and surface effects [25]. Research has also been directed toward computational techniques, particularly with crack tip elements that incorporate singular behavior. These studies include both linear elastic behavior and nonlinear response. In the latter case, some efforts focus on the HRR singularity [26]. A number of studies have concentrated on developing J integral solutions for various component geometries. These efforts, although carried out in the context of tearing instability [27], will also be useful in characterizing the driving force for FCP when the confined flow assumption of LEFM is violated. Related work [28] suggests that J might correlate FCP and be an appropriate measure of the driving force under such circumstances. Several questions remain, however, as to the definition in the range of J under certain cyclic loading histories, and until these questions are answered there is little proof that similitude between FCP processes will be provided for by J or by other inelastic measures of the driving force [29].

The past few years also have seen renewed interest in modeling variable amplitude FCP. Early studies in the 1970s [31, 31] attempted to account for the nonlinear nature of this process [29] by empirical adjustments to the linear model [32, 33]. In one approach [30] a ratio of LEFM plastic zone sizes created by various levels of the loading was used to account for retardation under overload cycles. Although this approach was partly successful, it could not be used without empirical calibration for the history of interest. Unfortunately, all such models rely on this calibration, some more than others. In addition, because the calibration is history sensitive, predictions were always somewhat uncertain. More recent work has followed those same lines [34] with the exception of the ligament model of Furing [35], which is an extension of the ligament concept of Kraft [36] advanced for constant amplitude corrosion fatigue. Although scientifically appealing, this model is very complex, requiring extensive calibration and entailing significant computer costs when it is applied cycle by cycle. It is certainly clear that many of the current models fail to achieve similitude between the driving force for growth under variable amplitude circumstances and that in the constant amplitude data base. However, often due to the nature of the histories being examined, adequate engineering predictions seem to result from these models. One interesting by-product of the recent empirical studies is that the myth that compression cycles do not contribute to crack propagation has been dispelled by experiments done to calibrate these models [34].

A number of interesting studies have been made with regard to macrocrack growth near limit load conditions. They characterize both the driving force for near limit load FCP [28] and the resistance of materials to that driving force [37]. In one study, cyclic loading gave rise to values of $K_{IC}$ equal to those obtained under the more usual monotonically increasing load [37]. Equal or greater values of $K_{IC}$ are often observed as a fatigue crack grows unstable. Such data are no cause for concern; they serve only to confirm the utility of $K_{IC}$ as developed per ASTM Spec E399. By way of contrast, other data show that fatigue cracks can become unstable at combinations of stress and crack size below that based on $K_{IC}$ [38]. In such cases, cyclic loading has a deleterious effect on toughness as measured in terms of $K_{IC}$. This potentially negative effect of cyclic loading on toughness must be understood before rational predictions of structural fatigue and fracture resistance can be made. While a problem of all structures, it may be particularly acute in dealing with environmentally assisted growth. In such cases, a value of K is commonly stated below which growth is not considered to occur. Cyclic loading can alter this number so that once again similitude is a concern. Although standardized tests such as E399 are convenient, they can generate data

that do not adequately reflect the service situation. Care must be taken, therefore, to ensure that similitude is achieved not only in the test geometry but also in the loading and environment.

Numerous studies of the FCP at low values of stress intensity have also been reported [39]. The primary concern for near threshold $\Delta K_{th}$ studies resides in the desire of the designer to limit or avoid the growth of defects. Techniques for the study of both $\Delta K_{th}$ and factors that control it have been of concern. Incremental and continuous load shedding schemes have been popularized to the extent that they are now the subject of a standardization round-robin test program [40].

The present focus is on $\Delta K_{th}$ rather than on techniques to establish it. It is significant that the growth rate near $\Delta K_{th}$ can be less than one interatomic spacing. The process can therefore be discontinuous in time and along the crack advance front. Results indicate that the process is microstructurally sensitive [41] and has a marked dependence on crystallographic orientation and grain size. Other studies suggest that environment might be a dominant factor [42]. Another complicating feature is the mixed mode nature of the growth; some authors argue that Mode II shear growth is responsible for near $\Delta K_{th}$ growth [43].

Other significant factors include mean stress and temperature [44]. Perhaps the most perplexing data are those in which microstructural variations that improve $\Delta K_{th}$ tend to reduce the so-called endurance limit [45]. Care is thus necessary to ensure that similitude is achieved not only in test parameters but also in the metallurgical character of the materials being examined. Yet another aspect of similitude at low values of $\Delta K$ has to do with the crack length used to obtain a low value of $\Delta K$. Thus far low $\Delta K$ has been achieved by using macrocracks tested at low stresses. The next section considers microcracks examined at moderate to high stresses.

***Microcrack growth.*** Microcrack growth has been one of the most popular research topics in the last several years. Included are fundamental studies in metallurgy and mechanics [46-50] and some basic phenomenological studies [50-55]. In contrast to the work at low stress intensities in long cracked specimens, growth at comparable LEFM stress intensities

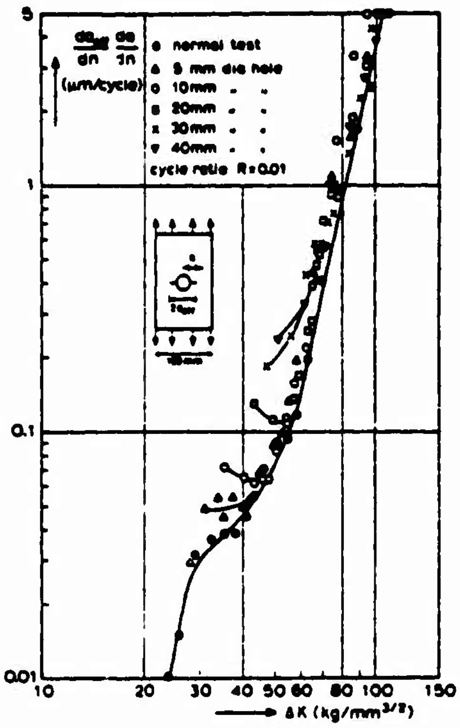


**Figure 5. Nonuniqueness in Growth Rate as a Function of Stress Intensity [15]**

in geometrically short cracks apparently occurs at higher rates. Figure 5 illustrates this for intermediate growth rates in circularly notched 2024-T3 aluminum sheets. Subsequent work by Gowda, Topper, and Leis [55], who modified the Bowie solution [56] after Neuber [57] to account for inelastic action, showed a correlation of crack propagation rates in inelastically strained circularly notched steel plates. They noted that the correlation was no longer linear on logarithmic coordinates of growth rate and stress intensity. Thereafter, others [51-53] also noted such an effect for problems of confined flow.

One model based on purely empirical arguments appears to consolidate the short crack behavior [51]. The essence of this model is that the effective length of a crack near a free surface is greater than the physical length of the crack. The authors argue that the effective length is equal to the physical length plus some constant amount, denoted $\ell_0$, which is characteristic of a given material and material condition. Values of this constant are simply estimated by comparing threshold FCP data with

endurance limit data for smooth specimens using LEFM:

$$\ell_0 = \frac{1}{\pi} \left( \frac{\Delta K_{TH}}{\Delta eE} \right)^2 \qquad (1)$$

In the equation $\Delta e$ is the endurance strain range and E is Young's modulus. To date the utility of this model has been demonstrated for a variety of materials.

The general utility of the model, however, is open to question for a number of basic reasons, the most important of which is that it does not address the actual problem. It does circumvent the apparent shortcoming of LEFM in consolidating short crack data -- that is, it makes the symptom of nonunique growth rates for constant LEFM $\Delta K$ disappear -- but a recent study [54] that shows short crack behavior for physically long cracks (0.1 in. and 0.5 in. in an aluminum and a steel, respectively) indicates that the concept as expressed in Equation (1) is not general.

Although appealing because of their simplicity, these data suggest that empirical modification of the LEFM $\Delta K$ to achieve a unique relationship between it and FCP growth rate is unsatisfactory. As indicated in the discussion of prediction schemes for variable amplitude FCP, a parameter that achieves similitude in the damage rate processes is required. Although $\Delta J$ might be appropriate in that context, recent as yet unpublished [50] data suggests that $\Delta J$ will not consolidate the data cited above [54].

Before an appropriate parameter is found, some basic research is required to establish the variables that govern the evolution of just-initiated cracks growing in gradient fields. Such studies should consider both analyses and experiments. In addition, models useful to the engineering community should be developed. Factors that should be addressed in these studies include: (1) the role of such metallurgical features as grain size and martensite packet size (i.e., factors pertaining to the breakdown of continuum concepts); (2) the apparent coupling of Mode I and Mode II microcracking; (3) the predamaging of material ahead of the crack in the notch field due to such factors as cyclic inelastic action changing hardness; (4) the branching of microcracks and its influence on stress intensity; (5) the multiplicity of initiation sites and the complex behavior of the surface crack as compared to the plane fronted crack; (6) the influence of the free surface on both the stress state and restraint to plastic flow; (7) the accuracy of handbook solutions for infinite domains in applications to finite domains where boundary proximity effects are significant; (8) the accuracy of crack length measurements; and (9) the ratios of notch and crack tip plastic zone sizes to the crack size. Certainly not all of these issues are critical in every problem, but until their role is resolved there will be uncertainty in life predictions, particularly in the area of microcrack propagation. Some of these issues have been pursued at length elsewhere [58, 59].

Given the above list of factors that affect the FCP rate in a gradient field, the achievement of similitude in a purely analytical fashion might be impossible. It should be emphasized that a unique measure of the damage rate is sought in a parameter such as K or J. Factors such as those involving metallurgy can therefore be accommodated only on a case by case basis through calibration by experiment. The experiment must faithfully reproduce the circumstances at hand, however.

***Thermal, environmental and multiaxial aspects.*** Characterization of the damage rate process in situations in which mechanical and perhaps metallurgical variables dominate has been of concern thus far. In industries involved with power generation and petrochemicals, however, damage analysis is complicated by multiaxial loading and by thermally activated and environmentally dependent damage mechanisms beyond the usual reversed plasticity FCP process.

An excellent extensive review published in 1977 [60] pertains to high temperature fatigue and thermal mechanical fatigue. Other good review papers are available [61-63]. In general, no single parameter exists that correlates the wealth of available data. For that matter, no single parameter has received universal acceptance for consolidating even limited data bases. It seems that, in the interim, the best approach is one that demands little from a damage parameter. Unfortunately such an approach requires test data that closely match the service situation; the reason is that the uncertainty in the damage parameter is circumvented by test conditions that simulate reality on a case by case basis.

As with high temperature problems, both environmental and multiaxial aspects have been the subject of specific reviews. Environmental aspects have been considered recently [64, 65] as has multiaxiality [66]. Again no single parameter has emerged that is universally accepted. A number of mechanisms have been postulated in the environmental area; each seems to work for a restricted class of problem. As with high temperature problems, the best approach may well be experiments that reasonably simulate the service situation on a case by case basis. With regard to multiaxiality, octahedral shear measures tend to be most widely accepted during crack nucleation for proportional stressing [66]. In contrast, recent work [67] indicates such measures will be inappropriate for dealing with damage assessment during nonproportional stressing. With regard to propagating cracks, a recent extensive study [68] concludes for confined flow at crack tips that $\Delta K$ adequately consolidates FCP data. This result is consistent with most of the relevant data.

## COMMENTARY

Difficulties in making accurate fatigue and FCP life predictions have been traced to an inability to match the damage process in the structure with that in some simple laboratory geometry. Although it is economically advantageous to use currently available technology and data to solve such an engineering problem, care must be taken to understand the uncertainty built into the answer when obtained that way. If the problem at hand is ill defined and uncertainty abounds, such an approach is all that is warranted. On the other hand, if highly accurate predictions are sought, experience has shown that similitude must be achieved.

Consideration must be given to the material, the loading, and the environment. The structure of concern must be correctly modeled. The gradient at a notch has been shown to influence the cycles to initiation and the FCP growth rate. The net size of the part will likewise be a factor; test geometries should be sized with this in mind. The elastic stress concentration factor, notch gradient, and net section size should be chosen accordingly when model components are used to simulate their full scale counterparts.

Life prediction should in general encompass both initiation and growth. Experience now suggests that if care is taken to ensure similitude, reasonable predictions of component life can be made in the absence of thermal and environmental influences. Major problem areas remain, however. In particular, research is needed with regard to (1) crack initiation and growth in gradient fields, (2) thermal and environmental effects, (3) multiaxial aspects, and (4) inelastic fracture mechanics.

## SUMMARY AND CONCLUSIONS

Ensuring similitude between damage processes being compared has been shown to be an essential part of making structural life predictions using simple laboratory test data. Similitude in the context of crack nucleation and macro- and microcrack growth was considered. Limited consideration was also given to high temperature, environmental, and multiaxial aspects.

The primary conclusion is that, when care is taken to ensure similitude, accurate life predictions can be made. However, such similitude is difficult to achieve in many cases because detailed understanding of the factors controlling the damage rate process is lacking. Research to gain this understanding is necessary before the major remaining problem areas can be resolved.

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# BOOK REVIEWS

## KINEMATICS AND DYNAMICS OF PLANAR MACHINERY

B. Paul
Prentice Hall, Inc., Englewood Cliffs, NJ
1979, 670 pages

Twenty years ago, mechanism design was done by graphical construction using simple analytical tools. The designer now can utilize analog and digital computers to design complicated mechanisms. Graphical methods have not been discarded, however; rather, they are being used in conjunction with the latest computing tools. This book is a comprehensive treatise of the subject of mechanisms.

The book is divided into three parts. Part I is concerned with geometrical kinematics. The first two chapters discuss terminology and include the kinematic analysis of four-bar mechanisms (slider crank, scotch yoke, pantograph, and Geneva wheel) and complex vectors, including the Coriolis theorem.

Chapters III and IV consider different types of common gears (spur, helical, bevel, and worm), various gear train arrangements, and different types of tooth profiles including their method of manufacture. Variations in cam design are described. The graphical and mathematical approaches are followed.

Chapter V describes the motion of lamina and considers the equations for centroids; relative motion of three planes (Kennedy-Arenhold theorem); and mechanical applications of trachoids, the isochronous pendulum, and root's blower. Velocity and acceleration equations are applied to common moving lamina. Chapter VI has to do with graphical construction in kinematics.

Part II is concerned with mathematical and analytical graphics. Chapters VII and VIII describe a single loop mechanism and lead into degrees of freedom and constraints in kinematics. LaGrange's equation is introduced; independent loop mobility criteria and simple approaches adapted from topology of networks are given.

Chapter IX contains simple application of LaGrange's equation: position analysis and the Newton-Raphson equations for numerical solution using computer program.

Chapter X has to do with mathematical application of velocity and acceleration to a number of different mechanisms, including solution of differential equations and some computer programs.

Part III presents comprehensive coverage of the analytical approach. Chapter XI is concerned with the status of mechanisms enveloped in vertical work, generalized forces, friction, and dead load. Chapter XII considers the dynamics of a single-degree-of-freedom system. The author applies the generalized equation of motion to various types of mechanisms. Equilibrium conditions are precisely explained using simple applications and illustrations. The chapter concludes with a fine section on reciprocating engine dynamics, transient engine performances, and flywheel dynamics. The illustrations and computer programs will be of value when the equations are used.

Chapter XIII explains balancing methods for equipment, including rotors. Balancing machines and instrumentation are discussed and applied to inertia balancing of multi-cylinder engines and planar linkages. Chapter XIV introduces multi-degree-of-freedom mechanisms and general computer programs that can be applied to mechanism theory.

The appendices explain in detail Grashof's theorem, complex numbers, concepts from theory of graphs, and matrices, and present additional computer programs.

This book is an excellent text. The reviewer would have preferred a section on finite elements because mechanism theory will eventually use this powerful method which is at present being extensively used in other areas of mechanics. The book can be utilized

as a reference book and is highly recommended to all designers and analysts interested in dynamics of machinery and its applications.

H. Saunders
General Electric Company
Schenectady, NY 12345

## NONDESTRUCTIVE EVALUATION AND FLAW CRITICALITY FOR COMPOSITE MATERIALS

R.B. Pipes, Editor
American Society for Testing and Materials
(STP 696), Philadelphia, PA, 1979, $34.50

This book contains the proceedings of the Nondestructive Evaluation and Flaw Criticality for Composite Materials Symposium that was held in Philadelphia, Pennsylvania in October, 1978. The meeting was sponsored by the American Society for Testing and Materials Committee D-30 on High Modulus Fibers and Their Composites.

The primary goals of the book as stated in the introduction are:

- To present the state of the art of nondestructive inspection methodologies for composite materials and to assess deficiencies
- To evaluate analytical methods for the description of critical flaw geometries and growth phenomena in composite materials
- To develop a basic understanding of failure phenomena and to establish methods of fractography for composite materials
- To promote an exchange among engineers, material scientists, and physicists leading to development of the unified technology necessary for certification of composite structures

The initial section of this book includes conference papers that treat nondestructive evaluation methodology for composite materials. Ultrasonic, holographic, neutron radiographic, liquid crystal, and vibrothemography techniques for the detection of damage in composite materials are the specific subjects treated.

The second section covers papers on flaw criticality of composites. The papers address the topics of what, where, when, and how to look for flaws; the formulation of analytical models for different predictions of critical flaw sizes, mode of failure, lifetime, and residual strength; and experimental confirmation of analysis predictions.

The final section contains papers on flaw characterization in composite materials. Subjects include environmentally enhanced surface damage and microstructure degradation in graphite/epoxy, the initiation and growth of damages around embedded flaws in graphite/epoxy, the location of fracture origins and fracture surface characterization in graphite/epoxy, and the detection and characterization of inherent defects in graphite/aluminum.

This book will serve both the engineer and material scientist as an excellent general reference for information concerning nondestructive evaluation and flaw criticality for composite materials.

S.E. Benzley
Associate Professor of Civil Engineering
Brigham Young University
Provo, Utah 84601

## MÉCANIQUE DES VIBRATIONS LINÉAIRES

M. Lalanne, P. Berthier, and J. Der Hagopian
Masson Publ., Paris, France
1980, 214 pages (in French)

This is a very useful addition to the extensive list of books available for a first course in mechanical vibrations. In just over 150 pages, the authors present both the important classical techniques (equations of motion in matrix notation and the Rayleigh energy method) and the important modern techniques (numerical integration algorithms and the finite element method). There is also a chapter on experimental measurement. In the opinion of the reviewer, the choice of topics and the extent of coverage is ideal for a first course. However, the book does assume a substantial knowledge of dynam-

ics, strength of materials, and matrix algebra. Instructors will have to supplement the text if their students lack any of this preparation.

An especially valuable feature of the book is the exercises. Answers are given to each, and in selected cases the solutions are worked out in detail. Most of the exercises supplement the text, and anyone working through the full set (about 75) will learn a great deal about solving vibration problems. As is appropriate in this day and age, many of the exercises require the use of a computer. In case appropriate computer programs are not available, the authors provide listings for eleven programs (in BASIC) that can be implemented on a machine with a 16K memory. The exercises and p ograms have been selected from those used by the authors at the Institut National des Sciences Appliquées de Lyon.

The coverage is divided into seven chapters:

| | |
|---|---|
| Chapter I | Systems with One Degree of Freedom (free vibration, forced vibration, damping, Rayleigh's method, applications) |
| Chapter II | Systems with Two Degrees of Freedom (free vibration with and without damping, forced vibration with and without damping, the vibration absorber) |
| Chapter III | Systems with N Degrees of Freedom (matrix formulation of the equation of motion, calculation of frequencies and modes, solution by modal expansion and numerical integration) |
| Chapter IV | Continuous Systems (bars, beams and plates, calculation of frequencies and modes, forced response) |
| Chapter V | Calculations by Finite Elements |
| Chapter VI | Experimental Aspects (transducers, exciters, measurement systems) |
| Chapter VII | Computer Programs (language and procedures, description of programs, listings) |

The reviewer highly recommends this book for its combination of brevity, clarity, and emphasis on modern solution methods. It is hoped that an English translation will soon be provided so that American students can benefit from this modern view of an important area of engineering education.

F.C. Nelson
College of Engineering
Tufts University
Medford, MA 02155

# SHORT COURSES

## AUGUST

### MACHINERY DATA ACQUISITION

Dates: August 3-7, 1981
September 28 - October 2, 1981
December 7-11, 1981

Place: Carson City, Nevada

Objective: This seminar is designed for people whose function is to acquire machinery data for dynamic analysis, using specialized instrumentation, and/or that person responsible for interpreting and analyzing the data for the purpose of corrective action on machines. Topics include measurement and analysis parameters, basic instrumentation review, data collection and reduction techniques, fundamental rotor behavior, explanation and symptoms of common machinery malfunctions, including demonstrations and case histories. The week also includes a lab workshop day with hands-on operation of the instrumentation and demonstration units by the participants.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

### RELIABILITY AND LIFE TESTING

Dates: August 10-14, 1981

Place: Los Angeles, California

Objective: To cover the following subjects: methodologies to improve the reliability of components, equipment and systems; follow their reliability growth; identify the distributions of their times-to-failure; determine their mean life, their reliability, and their failure rate, with their confidence limits at specified confidence levels; various new small-sample-size, short-duration reliability and life tests; nonparametric reliability and life tests; sequential tests for the exponential and binomial cases; tests of comparison for the exponential, Weibull and binomial cases; accelerated life testing; Bayesian life and reliability testing; identification of the appropriate times-to-failure distributions to use and the application of goodness-of-fit tests to distributions fitted to data; probability plotting techniques to find the parameters of the appropriate distributions to use.

Contact: Mr. Robert Rector, Assistant Director - Short Courses, UCLA, 6266 Boelter Hall, Los Angeles, CA 90024 - (213) 825-3496/1295/3344.

### FOUNDATIONS OF ENGINEERING ACOUSTICS

Dates: August 10-21, 1981

Place: Cambridge, Massachusetts

Objective: This summer program is a specially developed course of study which is based on two regular MIT subjects (one graduate level and one undergraduate level) on vibration and sound in the Mechanical Engineering Department. The program emphasizes those parts of acoustics - the vibration of resonators, properties of waves in structures and air - the generation of sound and its propagation that are important in a variety of fields of application. The mathematical procedures that have been found useful in developing the desired equations and their solutions, and the processing of data are also studied. These include complex notation, fourier analysis, separation of variables, the use of special functions, and spectral and correlation analysis.

Contact: Director of Summer Session, Room E19-356, Massachusetts Institute of Technology, Cambridge, MA 02139.

### PYROTECHNICS AND EXPLOSIVES

Dates: August 17-21, 1981

Place: Philadelphia, Pennsylvania

Objective: The seminar combines the highlights of Pyrotechnics and Solid State Chemistry, given the last twelve summers, and Explosives and Explosive Devices that made its successful appearance ten years ago. Similar to previous courses, the seminar will be practical so as to serve those working in the field. Presentation of the theory is restricted to that necessary for an understanding of basic principles and successful application to the field. Coverage empha-

sizes recent effort, student problems, new techniques, and applications.

Contact: Mr. E.E. Hannum, Registrar, The Franklin Research Center, Philadelphia, PA 19103 - (215) 448-1236/1395.

**MACHINERY VIBRATION ANALYSIS**
Dates: August 18-21, 1981
Place: New Orleans, Louisiana
Dates: October 6-9, 1981
Place: Houston, Texas
Dates: November 3-6, 1981
Place: Atlanta, Georgia
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow speed paper rolls.

Contact: Dr. Ronald L. Eshleman, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

**VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION**
Dates: August 24-28, 1981
Place: Santa Barbara, California
Dates: October 5-9, 1981
Place: Bournemouth, England
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

**MECHANICAL ENGINEERING**
Dates: August 31 - September 4, 1981
Place: Carson City, Nevada
Objective: This course is designed for the mechanical or maintenance engineer who has responsibility for the proper operation and analysis of rotating machinery. Working knowledge of transducers, data acquisition instrumentation and fundamental rotor behavior is a prerequisite. The course includes: a guest speaker in the field of machinery malfunctions; descriptions and demonstrations of machinery malfunctions; discussions of the classification, identification, and correction of various machine malfunctions; a one day rotor dynamics lab with individual instruction and operation of demonstration units; and emphasis on the practical solution of machinery problems rather than rotor dynamic theory.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

## SEPTEMBER

**ROTOR VIBRATION ANALYSIS**
Dates: September 1-3, 1981
Place: Edinburgh, UK
Objective: An intensive course for engineers involved in the vibration analysis of rotors supported in journal bearings. The course will also be useful to engineers who have professional responsibility for the maintenance of rotating plant. The main feature of the course will be on-line computation of the response and stability of rotor bearing systems. This will be preceded by an outline of the theoretical methods used and followed by practical demonstrations of contemporary monitoring equipment.

Contact: R.D. Brown, Department of Mechanical Engineering, Heriot-Watt University, Riccarton, Currie, Edinburgh, EH14 4AS - (031) 449-5111, Ext. 2387,9.

**10TH ADVANCED NOISE AND VIBRATION COURSE**

Dates: September 14-18, 1981
Place: Southampton, England
Objective: The course is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. The course, which is designed to refresh and cover the latest theories and techniques, initially deals with fundamentals and common ground and then offers a choice of specialist topics. The course comprises over thirty lectures, including the basic subjects of acoustics, random processes, vibration theory, subjective response and aerodynamic noise, which form the central core of the course. In addition, several specialist applied topics are offered, including aircraft noise, road traffic noise, industrial machinery noise, diesel engine noise, process plant noise and environmental noise and planning.

Contact: Mrs. O.G. Hyde, ISVR Conference Secretary, The University, Southampton, S09 5NH, England - (0703) 559122 X 2310/752, Telex 47661.

**BASIC INSTRUMENTATION SEMINAR**

Dates: September 15-17, 1981
Place: New Orleans, Louisiana
Dates: October 20-22, 1981
Place: Houston, Texas
Dates: October 27-29, 1981
Place: Pittsburgh, Pennsylvania
Objective: This course is designed for maintenance technicians, instrument engineers, and operations personnel - those individuals responsible for installation and proper operation of continuous monitoring systems. An in-depth examination of probe installation techniques and monitoring systems including types, functions, and calibration procedures is provided. Also presented is an overview of some of the instrumentation used to acquire data for vibration analysis, including oscilloscopes, cameras, and specialized filter instruments.

Contact: Kathy Fredekind, Bently-Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611, Ext. 224.

## OCTOBER

**UNDERWATER ACOUSTICS**

Dates: October 5-9, 1981
Place: University Park, Pennsylvania
Objective: This course is designed to introduce the basic principles and concepts of underwater acoustics to those new to the field as well as to serve as a refresher for those who need to become acquainted with recent advances. T[illegible] presented include underwater sound propagation, sonar concepts, ambient noise and reverberation considerations, transducer technology, nonlinear acoustics and parametric arrays, target physics, and radiated and self noise due to turbulent flows and cavitation.

Contact: Alan D. Stuart, Course Chairman, The Applied Research Laboratory, The Pennsylvania State University, P.O. Box 30, State College, PA 16801 - (814) 865-1397.

**DESIGN OF FIXED OFFSHORE PLATFORMS**

Dates: October 5-16, 1981
April 5-16, 1982
Place: Austin, Texas
Objective: This course is dedicated to the professional development of those engineers, scientists, and technologists who are and will be designing fixed offshore platforms to function in the ocean environment from the present into the twenty-first century. The overall objective is to provide participants with an understanding of the design and construction of fixed platforms, specifically the theory and processes of such design and the use of current, applicable engineering methods.

Contact: Continuing Engineering Studies, College of Engineering, Ernest Cockrell Hall 2.102, The University of Texas at Austin, Austin, Texas 78712 - (512) 471-3506.

**VIBRATION CONTROL**

Dates: October 12-16, 1981
Place: University Park, Pennsylvania
Objective: The seminar emphasizes principles, general approaches and new developments, with the

aim of providing participants with efficient tools for dealing with their own practical vibration problems.

Contact: Debra A. Noyes, 410 Keller Conference Center, University Park, Pennsylvania 16802 - (814) 865-8820, TWX No: 510-670-3532.

## FEBRUARY

### BALANCING OF ROTATING MACHINERY

Dates: February 23-25, 1982
Place: Houston, Texas
Objective: The seminar will emphasize the practical aspects of balancing in the shop and in the field. The instrumentation, techniques, and equipment pertinent to balancing will be elaborated with case histories. Demonstrations of techniques with appropriate instrumentation and equipment are scheduled. Specific topics include: basic balancing techniques (one-and two-plane), field balancing, balancing without phase measurement, balancing machines, use of programmable calculators, balancing sensitivity, flexible rotor balancing, and effect of residual shaft bow on unbalance.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

# NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

**Call for Papers**

**SYMPOSIUM ON ADVANCES AND TRENDS IN STRUCTURAL AND SOLID MECHANICS**
**October 4-7, 1982**
**Sheraton National Motor Hotel**
**Washington, D.C.**

The purpose of the symposium is to provide a multidisciplinary medium for communicating recent and projected advances in applied mechanics, applied analysis, numerical analysis, computer hardware and software and their impact on structural and solid mechanics.

Papers are invited on the impact of development in each of the following areas on structural and solid mechanics:

*Applied Mechanics and Engineering*

- New structural theories and their formulation (including theories needed for interaction problems)
- Constitutive laws for new structural materials and severe environments
- Strength and failure theories

*Computer Science and Computer Hardware*

- Database design and management
- Advanced processors (e.g., parallel, pipeline and array processors)
- Distributed computing and networks
- Microprocessors and minicomputers
- Computer graphics
- Systolic arrays
- Artificial intelligence

*Applied Analysis*
Analytical solution techniques (e.g., asymptotic integration, integral equations, Newton's method, perturbation, collocation and others)

- Computer implementation of the above techniques for the analysis of general structural components
- Adaptation of the above techniques to general-purpose codes

*Numerical Analysis*

- Mathematical modeling techniques
- Solution strategies for nonlinear problems and adaptive methods
- Algorithms for new computing systems
- Advances in finite element technology and other discretization techniques
- Hybrid numerical methods

Also, papers are invited on the following application areas:

- Inelastic behavior, failure mechanisms and damage tolerance of fibrous composite structures
- Interaction problems (e.g., actively controlled structures, fluid-structure, soil-structure interaction and contact problems
- Large-area space structures
- Crash dynamics and vehicle crashworthiness
- Impact and penetration mechanics
- Earthquake resistant structures

Authors should submit five copies of an extended abstract of about 1,000 words including sample figures prior to October 16, 1981. Notification of acceptance will be given by November 30, 1981. Five copies of the final manuscript, complete with original drawings or glossy prints will be due by April 16, 1982.

One-page abstracts are also solicited on current research in progress for short presentations at special sessions. A volume of proceedings will be published before the meeting and the papers accepted will also be considered for publication in the Journal of Computers and Structures.

For further information, contact: Professor Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Research Center, Hampton, Virginia 23665 - (804) 827-2897.

# INFORMATION RESOURCES

## TACTICAL WEAPON GUIDANCE AND CONTROL INFORMATION AND ANALYSIS CENTER

### BACKGROUND AND MISSION

GACIAC is the Tactical Weapon Guidance and Control Information Analysis Center, an Information Analysis Center initiated by the Department of Defense (DoD) in March of 1976, administered by the Defense Logistics Agency (DLA), sponsored by the U.S. Army Missile Command (MICOM), and operated by IIT Research Institute (IITRI) since July of 1977.

GACIAC's mission is to assist the tactical weapon guidance and control community, both government and industry, by encouraging and facilitating the exchange and dissemination of technical data and information to effect coordination of research, exploratory development, and advanced technology demonstrations.

***GACIAC is an IAC.*** The purpose of the GACIAC is to fulfill the functions of a full-service Information Analysis Center (IAC). An IAC is a center that provides scientific and technical information and support services to both government and industry in a vital technical area. GACIAC's data base consists of computerized bibliographic information on thousands of documents dealing with various aspects of guidance and control and related technologies. This data base is constantly being expanded to incorporate the results of relevant research and development projects. Information sources include: technical reports from DoD, other government agencies, industry, and academic institutions; open literature, including foreign sources; unpublished papers; and proceedings from conferences, symposia, and conventions.

***Fields of Interest.*** GACIAC's fields of interest are in the technology of tactical weapon guidance and control and related analyses, hardware, subsystems, and systems. The tactical weapons included in the program are: missiles, rockets, bombs, submunitions, projectiles, and munition dispersing cannisters. Nuclear weapons are not included in GACIAC's fields of interest, unless a given nuclear weapon is specifically defined as being for tactical purposes.

***Technical Areas.*** GACIAC's technical areas are: theoretical performance calculations; system and subsystem simulation; instrument and seeker development and tests; inertial component and system development; control actuators and their power sources; aerodynamic and reaction jet control devices; development of computational techniques and hardware; special design test equipment and techniques; component design criteria; analytic test techniques; manufacturing process development; operational serviceability; environmental protection; and material areas.

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- To analyze, appraise, and summarize information and data on selected subjects.
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Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

## ABSTRACT CONTENTS

# MECHANICAL SYSTEMS

## ROTATING MACHINES

(Also see Nos. 1685, 1738, 1739, 1740, 1741, 1742, 1749, 1784)

### 81-1575

**Nonstationary Vibration during Acceleration through Two Critical Speeds (without Damping)**

S. Yanabe

Technological Univ. Nagaoka, Aza Nagamine 1603-1, Kamitomioka-Machi, Nagaoka-Shi, Niigata-Ken, Bull. JSME, 24 (188), pp 405-412 (Feb 1981) 5 figs, 3 tables, 4 refs

Key Words: Shafts (machine elements), Critical speeds

The nonstationary vibration of a rotating shaft which passes through two critical speeds successively under conditions of uniform acceleration is theoretically analyzed by both exact and approximate methods for the vibration, neglecting the damping force. Formulae for evaluating the maximum amplitudes and the rotational speeds of the nonstationary response are derived, and the evaluated values are compared with those obtained from the exact solution.

### 81-1576

**Experimental Analysis and Methods to Determine the Dynamic Behavior of Propulsion Shafting Systems**

L.J. Wevers

Instituut TNO voor Werktuigkundige Constructies, Delft, The Netherlands, Vibration Tech., Ned Akoestisch Genootschap, pp 13-35 (Jan 1980)

N81-15401

(In Dutch; English summary)

Key Words: Shafts (machine elements), Propellers, Marine propellers, Lateral vibration

The dynamic bending properties of propeller shafts were investigated. Measurements were taken at a full size laboratory facility and onboard ships. The aim of the measurements was to verify the results of a numerical calculation method with a finite element program developed to face lateral vibration problems in an early stage of the design of a ship's propulsion system.

### 81-1577

**Transmission Matrix Method for Calculation of Forced Attenuated Bending Vibrations (Übertragungsmatrizenverfahren zur Berechnung erzwungener, gedampfter Biegeschwingungen)**

H. Sollmann

Technische Universität Dresden, Germany, Maschinenbautechnik, 30 (2), pp 70-74 (Feb 1981) 4 figs, 1 table, 6 refs

(In German)

Key Words: Transmission matrix methods, Flexural vibration, Rotors, Bearings

This work concerns a transmission matrix method used for calculation of forced attenuated bending vibrations. Matrices are prepared by using complex notation. Internal attenuations as well as discrete and continuously distributed outer attenuations are considered. Transmission matrices and boundary conditions are described and such problems as inner bearings of high stiffness, different exciting possibilities as well as specialities at transition to rotating systems are studied.

### 81-1578

**VAWTDYN - A Numerical Package for the Dynamic Analysis of Vertical Axis Wind Turbines**

D.W. Lobitz and W.N. Sullivan

Sandia Lab., Albuquerque, NM, ASME Paper No. 80-WA/Sol-18

Key Words: Wind turbines, Rotors, Computer programs

This paper describes a package developed for the dynamic analysis of the Darrieus vertical axis wind turbine. The model on which the package is based includes the major rotor elastic degrees of freedom, gyroscopic effects, and structural damping.

### 81-1579

**Instabilities in Turbomachinery**

J.M. Vance

Mech. Engrg. Dept., Texas A&M Univ., College Station, TX, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, April 7-9, 1981, pp 107-113, 8 figs, 22 refs

Key Words: Turbomachinery, Stability, Design techniques, Computer-aided techniques

Rotordynamic instability, as encountered in turbomachinery, is defined in both practical and mathematical terms. The known causes of instability are described, and reported cases of costly instabilities in the field are referenced. The two major classifications of rotordynamic instability are described, and the mathematical basis for computer simulations of each is explained. Design modifications which have been used to suppress instabilities in turbomachinery are described, and major limitations of the present state-of-the-art are pointed out.

**81-1580**

**High Bypass Turbofan Component Development. Modification II**

G. Armstrong, J. Palladino, and L. Zirin

General Electric Co., West Lynn, MA, Rept. No. AFWAL-TR-80-2032, 93 pp (March 1980)

AD-A093 156/8

Key Words: Shafts (machine elements), Turbofans, Fans, Dynamic tests

The assembly, instrumentation, and test of a fan shaft dynamics simulation vehicle is reported. Testing included low speed mechanical checkout, followed by operation up to 45,000 RPM using high speed model balancing, as required. The procedure was repeated for two sets of bearing support stiffness values. Balance sensitivity of the rotor system was investigated by creating various amounts of unbalance in the fan disk, the turbine disk, and the shaft, and recording the vibratory response up to 45,000 RPM. Finally, a ten-hour endurance test was conducted, completing the requirements of the contract.

**81-1581**

**Ray Theory to Predict the Propagation of Broadband Fan Noise**

A. Kempton

Rolls-Royce Ltd., Derby, England, Rept. No. PNR-90030, 9 pp (1980)

N81-14794

Key Words: Fans, Fan noise, Noise propagation

The feasibility of using a ray theory approach to predict the propagation, attenuation and radiation of high frequency engine intake noise is illustrated. Good agreement is demonstrated between ray theory and mode theory predictions for the broadband noise radiated in the absence of flow from short cylindrical ducts and from ducts of slowly varying cross sectional area. The two prediction schemes are also in broad agreement concerning the variation with wall impedance of the SPL insertion loss. Several important conclusions are drawn concerning the radiation of broadband noise from cylindrical inlets, from inlets of varying cross sectional area, and from scarfed inlets (for which no modal solution is available).

**81-1582**

**Rotordynamics Analysis for the HPFTP (High Pressure Fuel Turbopump) of the SSME (Space Shuttle Main Engine). SSME Turbopump Technology Improvements via Transient Rotordynamics Analysis Final Report**

D.W. Childs

Louisville Univ., Louisville, KY, NASA-CR-161620, 63 pp (July 1980)

N81-15017

Key Words: Pumps, Seals, Rotors, Spacecraft, Space shuttles, Bearings, Damping coefficients, Stiffness coefficients

The results of both linear (stability and synchronous response) and transient nonlinear analyses are reported. Dynamic coefficients were developed for the HPFTP interstage seals, and introduced into the rotordynamic model. The influence on HPFTP rotordynamics of a change in interstage seals from the smooth stepped design to a smooth straight configuration was examined. The sensitivity of the stability and synchronous results to changes in bearing stiffnesses and damping was determined. The influence on rotordynamic stability of a change from the stiff symmetric bearing carrier design to an asymmetric bearing carrier configuration was also studied.

**81-1583**

**Rotor Model for Verification of Computation Methods (Rotormodell Zur Verifizierung Von Rechenverfahren)**

J.H. Argyris, W. Aicher, F. Karl, W. Kuemmerle, and M. Mueller

Stuttgart Univ., Inst. fuer Statik und Dynamik, W. Germany, ISD-262, 58 pp (1979)

N81-15467

(In German; English summary)

Key Words: Windmills, Rotary wings, Modal tests

In order to prove the quality of idealization and the validity of computation for windmills, a driven model of a windmill

with a 7.4 m diameter rotor was constructed. New data acquisition and data transmission systems with 16 channels and digitization in the rotating system were developed and tested. The dynamic response of the rotor blades to the cyclic loading of gravity was taken to compare measurements and computations. For the measurements and evaluation which were performed by a measurement system and a computer, the necessary software was built.

**81-1584**

**Full Scale Wind Tunnel Investigation of a Bearingless Main Helicopter Rotor**

Boeing Vertol Co., Philadelphia, PA, Rept. No. NASA-CR-152373; D210-11659-1, 608 pp (Oct 1980)

N81-11014

Key Words: Helicopters, Rotors, Wind tunnel tests, Stiffness, Damping

A stability test program was conducted to determine the effects of airspeed, collective pitch, rotor speed and shaft angle on stability and loads at speeds beyond that attained in the BMR/BO-105 flight test program. Loads and performance data were gathered at forward speeds up to 165 knots. The effect of cyclic pitch perturbations on rotor response was investigated at simulated level flight conditions. Two configuration variations were tested for their effect on stability. One variable was the control system stiffness. The second variation was the addition of elastomeric damper strips to increase the structural damping. The BMR was stable at all conditions tested. At fixed collective pitch, shaft angle and rotor speed, damping generally increased between hover and 60 knots, remained relatively constant from 60 to 90 knots, then decreased above 90 knots. Analytical predictions are in good agreement with test data up to 90 knots, but the trend of decreasing damping above 90 knots is contrary to the theory.

**81-1585**

**Wind Tunnel Evaluation of Aeroelastically Conformable Rotors**

R.H. Blackwell, R.J. Murrill, W.T. Yeager, Jr., and P.H. Mirick

Sikorsky Aircraft Division, United Technologies Corp., J. Amer. Helicopter Soc., 26 (2), pp 31-39 (April 1981) 17 figs, 1 table, 4 refs

Key Words: Helicopters, Rotors, Rotary wings, Wind tunnel testing

The concept of controlling blade dynamic twist to reduce rotor system loads and improve aerodynamic efficiency was investigated through wind tunnel testing and analysis. Blade design features which promote favorable dynamic twist were selected based on aeroelastic analysis. Two 9-ft diameter model rotors which permitted parametric investigation of blade torsional stiffness, tip sweep and camber were fabricated and subjected to forward flight testing. The azimuthal variation of dynamic twist was determined based on measured twisting moments. Results showed that relative to a conventional stiffness blade, 20 tp 40-percent reductions in vibratory flatwise and torsional moments and 10-percent reductions in power were achieved at an advance ratio of 0.3 by configurations which produced noseup elastic twist on the advancing blade. Hub vibration was also reduced by blades which reduced advancing blade total twist.

**81-1586**

**Transonic Rotor Noise: Theoretical and Experimental Comparisons**

F.H. Schmitz and Y.H. Yu

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-81236, 31 pp (Nov 1980)

N81-11012

Key Words: Rotors, Noise generation

Two complementary methods of describing the high speed rotor noise problem are discussed. The first method uses the second order transonic potential equation to define and characterize the nature of the aerodynamic and acoustic fields and to explain the appearance of radiating shock waves. The second employs the Ffowcs Williams and Hawkings equation to successfully calculate the acoustic far field. Good agreement between theoretical and experimental waveforms is shown for transonic hover tip Mach numbers from 0.8 to 0.9.

## POWER TRANSMISSION SYSTEMS

**81-1587**

**Bond Graph Modelling of Power Transmission by Torque Converting Mechanisms**

J.S. Stecki

Dept. of Mech. Engrg., Monash Univ., Clayton, Victoria, Australia 3168, J. Franklin Inst., 311 (2), pp 93-110 (1981) 9 figs, 2 tables, 11 refs

Key Words: Power transmission systems, Mechanical drives, Bond graph technique

Kinematically constrained motion is generally accepted as a fundamental requirement for a mechanism to function as a power transmitting device. There exists, however, a class of mechanism which although kinematically unconstrained, can, by incorporation of energy storage elements, function as a power transmitter. This paper concentrates on the formulation of a general bond graph model for the mechanism. The model possesses mixed causality and non-linear structure. Some results of digital simulation of the bond graph model of a particular mechanism are provided.

# STRUCTURAL SYSTEMS

## BRIDGES

**81-1588**

**Prediction of Impact Factor for Military Bridges**

V.J. Virchis

Inst. of Sound Vib. Res., Southampton Univ., UK, Rept. No. ISVR-TR-107, 112 pp (Dec 1979) PB81-130379

Key Words: Bridges, Moving loads, Beams, Variable cross section

A numerical study has been conducted on the dynamic response of nonuniform bridges subjected to the passage of heavy, multi-axle vehicles. For practical purposes, short span military bridges are made from lightweight components. As a consequence, the vehicle to bridge weight ratios encountered in this study have been as high as eight to one. The dynamic model is represented as a simply supported beam, with variable cross-section, being traversed by a multi-degree of freedom, spring-mass system with viscous damping. The mathematical model uses the method of normal modes to solve the equation of motion for the beam response. The model was designed to account for entry and exit step conditions to the bridge, initial dynamic conditions, as well as for the loss of wheel contact with the bridge surface. The performance of the computer model in calculating the dynamic response has been successfully demonstrated by the presentation of model results with strain records obtained from field trials.

## BUILDINGS

**81-1589**

**Wind Induced Torsional Loads on Structures**

A. Kareem

Dept. of Civil Engrg., Univ. of Houston, TX, Engrg. Struc., 3 (2), pp 85-86 (April 1981) 1 fig, 4 refs

Key Words: Buildings, Wind-induced excitation, Torsional excitation

In this report an outline for the development of torsional loads on a rectangular cross-section building has been presented in frequency domain. Through the use of the spatio-temporal characteristics of pressure fluctuations measured on a scale model in a wind tunnel, expressions for the torsional forcing function are developed based on numerical integration.

**81-1590**

**A Replacement for the SRSS Method in Seismic Analysis**

E.L. Wilson

Dept. of Civil Engrg., Univ. of California, Berkeley, CA, Intl. J. Earthquake Engrg. Struc. Dynamics, 9 (2), pp 187-192 (March-April 1981) 4 figs, 1 table, 8 refs

Key Words: Seismic analysis, Buildings, Root mean squares, Complete quadratic combination method

It is well-known that the application of the Square-Root-of-Sum-of-Squares (SRSS) method in seismic analysis for combining modal maxima can cause significant errors. Nevertheless, this method continues to be used by the profession for significant buildings. The purpose of this note is to present an improved technique to be used in place of the SRSS method in seismic analysis. A Complete Quadratic Combination (CQC) method is proposed which reduces errors in modal combination in all examples studied. The CQC method degenerates into the SRSS method for systems with well-spaced natural frequencies. Since the CQC method only involves a small increase in numerical effort, it is recommended that the new approach be used as a replacement for the SRSS method in all response spectrum calculations.

**81-1591**

**Seismic Damage Estimation for Low- and Mid-Rise Buildings in Japan**

C. Scawthorn

School of Civil Engrg., Kyoto Univ., Kyoto, Japan, Intl. J. Earthquake Engrg. Struc. Dynamics, 9 (2),

pp 93-115 (March-April 1981) 16 figs, 5 tables, 33 refs

Key Words: Buildings, Earthquake damage

While much effort has been spent on analysis of individual structures, building class seismic damage estimators, of value in disaster planning, codewriting, city planning, national hazards policy formulation, etc., have been little investigated. Based largely on data from Sendai City, Japan in the 12 June, 1978 Miyagiken-oki earthquake ($M_L = 7 \cdot 4$), estimators of seismic damage for low- and mid-rise buildings in urban Japan have been determined. The effects of structural changes on expected damage are estimated. With these two building class damage estimators, a large part of future seismic damage to urban Japan can be estimated, as well as the effects of various mitigation measures.

## TOWERS

**81-1592**

**Control and Dynamics Study for the Satellite Power System. Volume 1: MPTS/SPS Collector Dynamic Analysis and Surface Deformation**

S.J. Wang

Jet Propulsion Lab., Pasadena, CA, JPL-PUB-80-77-V-1, Rept. No. NASA-CR-163826, 113 pp (Sept 1980)

N81-14395

Key Words: Antennas, Vibration analysis

The basic dynamic properties and performance characteristics of the microwave power transmission satellite antenna were analyzed in an effort to develop criteria, requirements, and constraints for the control and structure design. The vibrational properties, the surface deformation, and the corresponding scan loss under the influence of disturbances are considered.

**81-1593**

**Measurements of Wind and Deformation on a High Radio Tower. Part 1: Introduction (Wind- und Verformungsmessungen an einem Funkturm. Teil 1: Einfuhrung)**

W. Neuerburg

Fachhochschule f. Technik Esslingen, Kanalstr. 33, D-7300 Esslingen, Fed. Rep. Germany, Techn Messen, 48 (3), pp 101-106 (March 1981) 10 figs, 2 tables, 5 refs

(In German)

Key Words: Towers, Wind-induced excitation, Vibration measurement

The wind loadings on a high tower structure and the coherent effects of static and dynamic responses were studied by means of a versatile measurement equipment. Thereby wind pressures against the tower wall, the deformation and oscillation of the structure and the free-streaming wind were measured with reference to the time.

## FOUNDATIONS

(See No. 1785)

## UNDERGROUND STRUCTURES

**81-1594**

**Earthquake Response Characteristics of Jointed and Continuous Buried Lifelines**

J.P. Wright and S. Takada

Weidlinger Associates, NY, Rept. No. NSF/RA-800210, 18 pp (Jan 1980) (Presented at the World Conference on Earthquake Engineering, 7th, Istanbul, September 1980)

PB81-120016

Key Words: Underground structures, Lifeline systems, Earthquake response, Harmonic response

Dynamic response curves of displacement versus frequency are calculated for the problem of forced harmonic response of jointed cylindrical structures in a homogeneous linearly elastic medium of infinite extent. Consistent with experimental observations, the results of a parametric study show that, for frequencies in the earthquake range, dynamic effects can be neglected for jointed or continuous buried pipelines made of concrete, cast iron, or steel, and having commonly used sizes. An exhaustive parametric study was not attempted because of the number of parameters in the model. An attempt was made to use parameters that would accentuate dynamic effects. From the present studies it is conjectured that resonant behavior cannot occur in typical buried pipelines for frequencies in the earthquake range so long as the pipe materials are stiffer than the surrounding soil and the joints are reasonably small relative to the length of the pipe segments.

**81-1595**

**Hydrodynamic Pressure on Arch Dams - By a Mapping Finite Element Method**

B. Nath
Dept. of Civil Engrg., Queen Mary College, Univ. of London, London, England, Intl. J. Earthquake Engrg. Struc. Dynamics, 9 (2), pp 117-131 (March-April 1981) 13 figs, 25 refs

Key Words: Dams, Hydrodynamic excitation, Seismic response, Finite element technique

A novel finite element method is proposed for the analysis of the uncoupled hydrodynamic pressures generated on arch dams due to a steady-state ground acceleration. In this method the equation governing hydrodynamic pressures and also the prescribed boundary conditions are all transformed from the Cartesian space to a logarithmically condensed cylindrical polar space; in this process the physical configuration of the reservoir-dam is also mapped into an 'image' domain. The transformed governing equation is then solved in the image domain, subject to the transformed boundary conditions, using standard finite elements. Because physical dimensions are logarithmically condensed in the image space, the proposed method is particularly suitable for dealing with large or very large aspect-ratio reservoir-dam systems, economically and efficiently. The high degree of accuracy which the proposed method is capable of, and also the simple way in which it can be applied to complex reservoir-dam shapes, have been demonstrated by means of examples. The method has also been applied to study the uncoupled hydrodynamic pressu.es on the upstream face of a cylindrical arch dam, generated by a steady-state vertical ground acceleration.

**81-1596**

**Full-Scale Experimental Investigation of a Modern Earth Dam**

A.M. Abdel-Ghaffar, R.F. Scott, and M.J. Craig
Earthquake Engrg. Res. Lab., California Inst. of Tech., Pasadena, CA, Rept. No. EERL-80-02, 204 pp (Feb 1980)
PB81-123788

Key Words: Dams, Experimental test data, Earthquake response, Prediction techniques

Extensive investigation of a modern earth dam's behavior during relatively intense shaking is reported. The study utilized records on full-scale dynamic tests recovered from the Santa Felicia Dam in Southern California. These records provided information on the dynamic characteristics of the dam which was instrumented with motion sensors. The project gathered experimental data used for testing and developing various analytical and numerical methods for computing the natural frequencies and mode shapes of dams and, particularly, for predicting earthquake response. Data on the dam's responses indicate the following: analytical or finite models are needed to represent the prototype realistically in vertical and longitudinal directions and to include coupling of these directional motions; more than two sets of strong-motion instruments should be deployed on and in the vicinity of the structure to obtain reliable information on a dam's three-dimensional behavior during an earthquake. Suggestions are made for the appropriate location of instruments.

**81-1597**

**Dynamic Response of Simple Arch Dams Including Hydrodynamic Interaction**

C.S. Porter and A.K. Chopra
Earthquake Engrg. Res. Ctr., California Univ., Berkeley, CA, Rept. No. UCB/EERC-80/17, 287 pp (July 1980)
PB81-124000

Key Words: Dams, Substructuring methods, Hydrodynamic excitation

The substructure method is adapted and generalized for response analysis of arch dams subjected to upstream-downstream, cross-stream and vertical components of ground motion. The arch dam is assumed to be a segment of a circular cylinder, bounded by vertical, radial banks of the river valley enclosing a central angle of 90 degrees. The arch dam and impounded water are treated as two substructures of the total system and displacements of the dam are represented as a linear combination of the first few natural modes of vibration of the dam alone. For this simple geometry of the arch dam and fluid domain, mathematical solutions of the wave equation are presented to determine the hydrodynamic terms in the finite element equations for the dam.

**81-1598**

**Vibrations and Resonance in Hydraulic Systems**

W. Zielke
Technische Universitaet, Hanover, W. Germany, Unsteady One Dimensional Flows in Complex Networks and Pressurized Vessels, Von Karman Inst. for Fluid Dyn., 26 pp (1980)
N81-15257

Key Words: Hydraulic systems, Vibration analysis, Linear theories, Nonlinear theories

Various types and causes of vibrations in hydraulic systems are reviewed and the pertinent methods of analysis outlined. Limitations of the linear versus the nonlinear analysis and of the deterministic versus the stochastic analysis are pointed out. Typical results of a resonance study of a pumped storage system are given.

## PRESSURE VESSELS

### 81-1599

**Acoustic Emission for Quality Control of Kevlar 40 Filament-Wound Composites**

M.A. Hamstad

Materials Test and Evaluation Section, California Univ., Livermore, CA, Rept. No. UCRL-83783; CONF-801010-1, 15 pp (Jan 1980) (Presented at the 12th Natl. Soc. for the Advan. of Mater. and Process Eng. Tech. Conf., Seattle, Oct 7-9, 1980) N81-11125

Key Words: Pressure vessels, Acoustic emission

The relationship of production variables to changes in proof-test-generated acoustic emission from NASA type filament wound pressure vessels was studied. Some of the deliberate manufacturing errors were matrix content, cure cycle, matrix component ratios, degraded fiber, moisture content, and winding tension. The 11 cm diameter spherical pressure vessels were made by filament winding Kevlar 49/epoxy on aluminum mandrels. After proof testing, the vessels were burst tested. Certain production variables resulted in significant changes in acoustic emission amplitude and associated stress level.

## POWER PLANTS

(Also see Nos. 1678, 1679)

### 81-1600

**Designing Against Low-Cycle Fatigue at Elevated Temperature**

S. Majumdar

Materials Sci. Div., Argonne Natl. Lab., Argonne, IL Nucl. Engrg. Des., 63 (1), pp 121-135 (Jan 1981) 11 figs, 2 tables, 22 refs

Key Words: Fatigue life, Nuclear reactor components

Factors that are important in determining low-cycle fatigue damage at elevated temperature are discussed. The linear damage rule for computing creep-fatigue damage is shown to be unsatisfactory in many situations. The damage-rate equations developed earlier have been generalized to include multiaxial creep-fatigue under complicated loading histories. Available creep-fatigue data under combined axial-torsion loading can be explained in a consistent manner by the damage-rate approach.

### 81-1601

**Seismic Analysis of ZPR-6 Reactor Facility**

H.U. Ahmed and D. Ma

Des. Engrg. Analysis, Engrg. Div., Argonne National Lab., Argonne, IL 60439, Nucl. Engrg. Des., 63 (1), pp 157-166 (Jan 1981) 9 figs, 14 refs

Key Words: Nuclear reactors, Seismic analysis

A safe shutdown earthquake analysis of ZPR 6 Reactor Facility (Zero Power Reactor) was conducted through seismic risk analysis, soil-structure interaction analysis, reactor building dynamic time history analysis and equipment response spectrum analysis due to an assumed El Centro earthquake. Several ASME, AISC and ANSI design codes were used to demonstrate the adequacy of this facility and to design several equipment and piping supports.

### 81-1602

**Homogenized Equations of Motion for Rod Bundles in Fluid with Periodic Structure**

U. Schumann

Kernforschungszentrum Karlsruhe, Institut f. Reaktorentwicklung, Postfach 3640, D-7500 Karlsruhe, Fed. Rep. Germany, Ingenieur-Archiv, 50 (3), pp 203-216 (1981) 7 figs, 16 refs

Key Words: Interaction: structure-fluid, Nuclear reactor components, Rods, Fluid-induced excitation

"Homogenized" or averaged equations of motion are deduced for linear dynamic fluid-structure interactions of rod bundles immersed in an acoustical fluid. The equations define an effective density tensor which couples the fluid

and rod accelerations. In the pressure wave equation a sound speed tensor arises. The theory assumes that the bundle consists of a periodic lattice of cells with diameters which are very small in comparison to the bundle diameter and that cell averages are smooth functions in space and time. The derivation is based on Hamilton's principle. For the specific case of circular cylindrical rods in a square pattern the tensors are given numerically and the fluid-structure interaction effects are discussed.

## OFF-SHORE STRUCTURES

### 81-1603
**Fatigue Fracture Mechanics Analysis of Offshore Structures**

W.D. Dover

Dept. of Mech. Engrg., Univ. College London, Torrington Place, London WC1E 7JE, England, Intl. J. Fatigue, 3 (2), pp 52-60 (April 1981) 17 figs, 2 tables, 17 refs

Key Words: Offshore structures, Fracture properties, Fatigue life

An assessment of a fatigue fracture mechanics procedure for fatigue life estimation of welded joints in offshore structures resulting from studies of variable amplitude loading, stress analysis and crack growth measurement in T-joints is presented.

### 81-1604
**Laboratory Tests for Dynamic Ice-Structure Interaction**

M. Maattanen

Dept. of Mech. Engrg., Univ. of Oulu, 90570 Oulu 57, Finland, Engrg. Struc., 3 (2), pp 111-116 (April 1981) 4 figs, 5 refs

Key Words: Interaction: ice-structure, Off-shore structures, Laboratory test data, Scaling

The CRREL test basin is able to simulate dynamic ice-structure interaction with scale model tests which cover the whole range of structures that are considered here. For bottom-founded structure simulation, a test pile was designed so that its stiffness, natural frequencies and modes and damping could be varied. The ice movement against the pile was arranged to have constant acceleration in order to excite different modes with differing ice velocities. The flexibility of the drive system caused jerky ice movements with low velocities. Analysis of the recorded ice forces and acceleration include the refinement at measured ice forces by eliminating the response of the measuring system itself using the dynamic equilibrium or transfer function approach. The frequencies and the damping of vibrations were analyzed using a Fourier signal analyzer. Scaling laws are discussed and it is noted that full similitude cannot be achieved for both ice interaction force and pile and ice vibrations.

# VEHICLE SYSTEMS

## GROUND VEHICLES
(Also see Nos. 1632, 1634)

### 81-1605
**Development of Compliance Test for Truck Rear Underride Protection. Volume II - Technical Report**

R. Baczynski and S. Davis

Dynamic Science, Inc., Phoenix, AZ, Rept. No. 8319-80-020A/1607, DOT-HS-805-592, 405 pp (Aug 1980)

PB81-136111

Key Words: Collision research (automotive), Dynamic tests, Trucks, Trailers, Articulated vehicles, Guard rails

The objective of this program was to develop static and dynamic compliance test procedures for truck/trailer rear underride protection. A static test facility and dynamic test device along with appropriate compliance test procedures were developed to test and evaluate rigid and energy-absorbing velocity-sensitive underride guards. A truck body simulator was also developed to effectively model the rear of truck/trailer bodies for mounting of selected guards during testing. The dynamic test device is an energy-absorbing honeycomb-faced bogey vehicle which simulates the front load/deflection characteristics of a typical current large car. The report summarizes the highlights of the tests of current small and large car-to-current production guards, ten car-to-rigid guard tests to determine the effects of speed, guard height, car size, and impact mode on underride and occupant response, and two tests of a production energy-absorbing guard. Based on the results of the crash tests and engineering analyses, recommendations are presented for underride guard requirements and compliance test procedures.

**81-1606**

**Dynamic and Static Evaluation of the Impact Stiffness of Truck Driver-Cabins (Dynamische und statische Untersuchung der Kollisions-Festigkeit von Lastkraftwagen-Fahrerhäusern)**

H. Bürger

Allensteinstrasse 4, 330 Braunschweig, ATZ, 83 (3), pp 121-124 (March 1981) 5 figs, 1 ref

(In German)

Key Words: Trucks, Collision research (automotive), Regulations

The ECE regulation No. 29 and the Swedish legislation require proof of adequate cabin stiffness by pendulum impact. By testing with a pendulum rig it was established that the kinetic energy will only partially be converted into deformation. The demonstration of the survival space introduces some problems. In introducing comparable deformation to the driver cabin, static loads will be essentially smaller in comparison with pendulum impact forces to achieve similar deformation. Test results from dynamic and static impact were compared.

**81-1607**

**Modal Analysis Technique for Acoustic Problem Solution**

R. Snoeys, P. VanHonacker, and P. Sas

Instituut TNO voor Werktuigkundige Constructies, Delft, The Netherlands, Afdeling Werkplaatstechniek, Vibration Tech., Ned. Akoestisch Genootschap, pp 1-12 (Jan 1980)

N81-15400

(In Dutch; English Summary)

Key Words: Modal analysis, Motor vehicles, Vibration control, Noise reduction

Structural vibration and noise measurements are related to several modeshapes, yielding a visual indication for the place and the type of the desired structural modification in order to reduce or eliminate the vibration noise problem. Some case studies from the automotive industries are presented, illustrating the effectiveness of the modal analysis technique in locating and solving noise as well as mechanical vibration problems.

## SHIPS

**81-1608**

**Component Mode Synthesis in Compact Form and Its Application to Ship Vibration**

R.E. Sandstrom

Univ. of Michigan, Ph.D. Thesis, 77 pp (1980)

UM 8106220

Key Words: Ship vibration, Component mode synthesis

This work presents a new condensed version of the component mode equations for the efficient solution of large structural vibration problems where the structural system is divided into many substructure units. New solution techniques, required for the solution of the component mode equations in compact form, are described. The application of the new compact procedure in ship vibration analysis is demonstrated. The advantages of the proposed compact form of component mode synthesis over the standard solution procedures are also demonstrated. The condensed component mode equations yield matrices of greatly reduced order without any significant sacrifice in physical or numerical accuracy. Hence, both computer storage requirements and computational effort are reduced significantly.

**81-1609**

**Time-Domain Method for Computing Forces and Moments Acting on Three Dimensional Surface-Piercing Ship Hulls with Forward Speed**

R.B. Chapman

Science Applications, Inc., LaJolla, CA, Rept. No. SAI-462-80-560-LJ, 40 pp (Sept 1980)

AD-A092 475/3

Key Words: Ship hulls, Time domain method

A time-domain simulation method for computing forces and moments acting on an arbitrary surface-piercing three-dimensional ship hull is presented. Arbitrary motions can be prescribed and are assumed to be sufficiently small so that the linearized method is valid. Forward speed effects are included under the assumption that the disturbance generated by forward motion is also small and interactions with the flow generated by the prescribed motions are of second order. The hull is represented by a set of quadrilateral surface panels in a body-fixed system, while the free surface is represented by its spectral coordinates in a space-fixed rectangular system. Small time steps are used to advance the flow.

## AIRCRAFT

(Also see Nos. 1584, 1585, 1629, 1630, 1631, 1633, 1635, 1646, 1652, 1745, 1751, 1793, 1794)

**81-1610**

**Assessment of Ground Effects on the Propagation of Aircraft Noise: The T-38A Flight Experiment**

W.L. Wilshire, Jr.

NASA Langley Research Ctr., Hampton, VA, Rept. No. NASA-TP-1747, L-13765, 128 pp (Dec 1980)
N81-14788

Key Words: Aircraft noise, Sound propagation

A flight experiment was conducted to investigate air to ground propagation of sound at gazing angles of incidence. A turbojet powered airplane was flown at altitudes ranging from 10 to 160 m over a 20-microphone array positioned over grass and concrete. The dependence of ground effects on frequency, incidence angle, and slant range was determined using two analysis methods. Theoretical predictions were found to be in good agreement with the major details of the measured results.

**81-1611**

**Prediction of Sound Radiated from Different Practical Jet Engine Inlets**

B. Zinn and W. Meyer

Georgia Inst. Tech., School of Aerospace Engrg., Atlanta, GA, Rept. No. NASA-CR-163824, 41 pp (1980)
N81-14789

Key Words: Jet engines, Sound waves, Computer programs

Existing computer codes for calculating the far field radiation patterns surrounding various practical jet engine inlet configurations under different excitation conditions were upgraded. The computer codes were refined and expanded so that they are now more efficient computationally by a factor of about three and they are now capable of producing accurate results up to nondimensional wave numbers of twenty. Computer programs were also developed to help generate accurate geometrical representations of the inlets to be investigated. This data is required as input for the computer programs which calculate the sound fields. This new geometry generating computer program considerably reduces the time required to generate the input data which was one of the most time consuming steps in the process. The results of sample runs using the NASA-Lewis QCSEE inlet are presented and comparison of run times and accuracy are made between the old and upgraded computer codes. The overall accuracy of the computations is determined by comparison of the results of the computations with simple source solutions.

**81-1612**

**Noise Prediction for Jetstar Prop-Fan Test**

F. Farassat, R.M. Martin, and G.C. Greene

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81916, 292 pp (Dec 1980)
N81-14790

Key Words: Aircraft noise, Noise prediction

The acoustic calculations reported in this memorandum are for two model prop-fan designs (SR-2 and SR-3 blades) scheduled for test on top of Jetstar aircraft. The predicted acoustic pressure signatures and spectra for selected microphone positions on the fuselage and operating conditions are presented. A detailed presentation of the input data, the acoustic results, and the corrections for microphone fuselage reflection are included. The general trend observed in these calculations is that the acoustically optimized model (using SR-3 blades) is substantially quieter than the model with SR-2 blades. This latter design has conventional straight blades.

**81-1613**

**Noise Characteristics of Two Parallel Jets with Unequal Flow**

B.N. Shivashankara and W.V. Bhat

Boeing Commercial Airplane Co., Seattle, WA, AIAA J., 19 (4), pp 442-448 (April 1981) 16 figs, 8 refs

Key Words: Jet noise, Aircraft noise, Noise reduction, Noise shielding

Many jet noise suppression devices employ tubes, lobes, and similar devices to break up the flow. To understand the suppression mechanisms of these devices, a two-parallel-jet model experiment was conducted. The three-dimensional noise field was mapped for the case when one jet was at a velocity of 549 m/s and a total temperature of 538°C (jet 1) and the other was at 351 m/s and 93°C (jet 2). Mean flow profiles were also obtained at three axial stations.

**81-1614**

**Two-Dimensional Analytical Model of Twin Jet Shielding**

C.H. Gerhold

Texas A&M Univ., College Station, TX 77843, J. Acoust. Soc. Amer., 69 (4), pp 904-908 (April 1981) 6 figs, 6 refs

Key Words: Aircraft noise, Noise reduction, Noise shielding

Estimation of the impact of jet noise requires analytical modeling not only of the noise source mechanism, but also

of the propagation of noise from source to receiver. One factor which influences the jet noise path is shielding of one jet by another in a twin jet configuration. An analytical model is developed to investigate the shielding phenomenon. The two-dimensional wave equation is solved for a stationary line source impinging upon a cylinder of heated flow. The solution estimates the diffraction and scattering of the incident sound wave by the shielding jet in a plane normal to the jet axis. The frequency dependence of the normalized sound pressure estimated by the model is found to agree in form with empirical data. The azimuthal redistribution of the incident sound shows that, as the frequency of maximum shielding is approached, the scattered sound becomes more highly concentrated into lobes adjacent to the shielding zone.

## 81-1615

### Installation Effects on Propeller Noise

H.K. Tanna, R.H. Burrin, and H.E. Plumblee, Jr.
Lockheed-Georgia Co., Marietta, GA, J. Aircraft, 18 (4), pp 303-309 (April 1981) 18 figs, 5 refs

Key Words: Propeller noise, Aircraft noise

The installation effects on propeller noise and propeller wake flow in flight have been examined experimentally by operating a model-scale propeller in the Lockheed anechoic open-jet wind tunnel. In particular, two aspects of propeller operation in a real situation have been quantified. These are: the effects of nonzero angle of attack or propeller inflow angle relative to the flight path, and the propeller inflow distortion due to the upwash generated by the presence of wing and flap behind the propeller. The results show that not only are these installation effects very important, but they are predicted inadequately using existing methods.

## 81-1616

### Characteristics of Propeller Noise on an Aircraft Fuselage

C.K. Barton and J.S. Mixson
NASA Langley Res. Ctr., Hampton, VA, J. Aircraft, 18 (13), pp 200-205 (Mar 1981) 15 figs, 5 tables, 13 refs

Key Words: Aircraft noise, Propeller noise, Noise measurement

Exterior noise was measured on the fuselage of a twin-engine, light aircraft at four values of engine rpm in ground static tests and at forward speeds up to 36 m/s in taxi tests. Propeller noise levels, spectra, and correlations were determined using a horizontal array of seven flush-mounted microphones and a vertical array of four flush-mounted microphones in the propeller plane. The measured levels and spectra are compared with predictions based on empirical and analytical methods for static and taxi conditions. Trace velocities obtained from point-to-point correlations are used to describe the propagating and rotating characteristics of the propeller noise field on the fuselage.

## 81-1617

### Current Developments in Aircraft Fatigue Evaluation Procedures

O. Buxaum and D. Schutz
Laboratorium fuer Betriebsfestigkeit, Darmstadt, Fed. Rep. Germany, Rept. No. AAAF-NT-79-33, ISBN-2-7170-0581-1, 34 pp (1979) (Presented at 14th Intl. AAAF Aeron. Congr. on New Develop. in Struct. and Mater., Paris, June 6-8, 1979)
N81-12464

Key Words: Aircraft, Fatigue life

Current developments in the field of aircraft fatigue evaluation are reviewed including the description of loads for fatigue evaluation, the damage tolerance concept, concepts for the prediction of fatigue life, fatigue life improvement during production, load transfer in mechanical joints, and the characteristics of the fiber reinforced materials. There is not yet a satisfactory theory to explain the fatigue mechanism. Fatigue testing is the most important tool in defining the life of aircraft structures.

## 81-1618

### Evaluation of Bird Load Models for Dynamic Analysis of Aircraft Transparencies

B. West and R. Brockman
Dayton Univ. Research Inst., Dayton, OH, Rept. No. UDR-TR-80-59, AFWAL-TR-80-3092, 87 pp (Aug 1980)
AD-A092 909/1

Key Words: Aircraft, Bird strikes, Testing techniques, Experimental test data, Computer programs

The objective of the program was to experimentally and analytically examine the range of applicability of existing bird loading models. The program consisted of two primary tasks; the design of an experiment and the collection of experimental data for actual bird impact on a flexible target,

and the computation of the response to the experimental impact conditions using the MAGNA code and existing bird loading models.

**81-1619**

**Active Flutter Suppression on an F-4F Aircraft with External Stores Using Already Existing Control Surfaces**

O. Sensburg, H. Hoenlinger, and T. Moll
Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Fed. Rep. Germany, Rept. No. MBB-FE-17/S/PUB/24, 9 pp (March 1980) (Presented at AIAA 21st Struct., Struct. Dyn. and Mater. Conf., Seattle, May 12-14, 1980)
N81-13972

Key Words: Aircraft, Flutter, Active flutter control

The flutter suppression system was flight tested using classical flight flutter tests, open loop tests, and closed loop tests. The control law was found by applying optimal control theory thus minimizing the control surface motion due to disturbances and providing the required stability margins. The selection of the wing mounted store configuration is described.

**81-1620**

**Effects of Angle of Attack and Ventral Fin on Transonic Flutter Characteristics of an Arrow-Wing Configuration**

R.V. Doggett and R.A. Ricketts
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81914, L-14114, 26 pp (Dec 1980)
N81-15397

Key Words: Aircraft wings, Flutter, Aerodynamic loads, Wing tunnel tests

Experimental transonic flutter results are presented for a simplified 1/50 size, aspect ratio 1.77, wind tunnel model of an arrow wing design. Flutter results are presented for two configurations; namely, one with and one without a ventral fin mounted at the 0.694 semispan station. Results are presented for both configurations trimmed to zero lift and in a lifting condition at angles of attack up to 4 deg. The results show that the flutter characteristics of both configurations are similar to those usually observed. Increasing angle of attack reduces the flutter dynamic pressure by a small amount (about 13 percent maximum) for both configurations.

**81-1621**

**Passive Control of Wing/Store Flutter**

W. Reed, F. Cazier, Jr., and J.T. Foughner, Jr.
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81865, L-14010, 19 pp (Dec 1980) (Presented at the 5th Joint Tech. Coordinating Group Aircraft Stores Compatibility Symp., St. Louis, Sept 9-11, 1980)
N81-13922

Key Words: Aircraft, Wing stores, Flutter, Vibration isolation

Results are presented for a passive flutter suppression approach known as the decoupler pylon. The decoupler pylon dynamically isolates the wing from store pitch inertia effects by means of soft spring/damper elements assisted by a low frequency feedback control system which minimizes static pitch deflections of the store because of maneuvers and changing flight conditions.

**81-1622**

**Active Control of an Explosive Wing-Store Flutter Case**

H. Hoenlinger, O. Sensburg, M. Kuehn, and H. Goedel
Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Fed. Rep. Germany, Rept. No. MBB-FE-17/S/PUB/25, 9 pp (April 1980) (Presented at 50th Mtg. Struc. and Mater. Panel of AGARD, Athens, April 13-18, 1980)
N81-13973

Key Words: Aircraft, Wing stores, Active flutter control

Control laws were calculated, using optimal control theory, to suppress an explosive wing store flutter case on a YF-17 dynamically scaled model. The trailing edge flap was used for flutter suppression because usually hydraulically driven ailerons are available in modern fighters.

**81-1623**

**Effects of Nonlinearities on Wing Store Flutter**

G. Deferrari, L. Chesta, O. Sensburg, and A. Lotze
Messerschmitt-Boelkow-Blohm G.m.b.H., Munich, Fed. Rep. Germany, Unternehmensbereich Raumfahrt, Rept. No. MBB-FE-17/S/PUB/27, 16 pp (April 1980) (Presented at 50th Mtg. Struct. and Mater.

Panel of AGARD, Athens, April 13-18, 1980)
N81-13974

Key Words: Aircraft, Wing stores, Flutter

The effects of structural nonlinearities, in particular friction and backlash, on the dynamic behavior of airplanes can be very important for flutter. Larger nonlinearities do exist on sweepable wing airplanes with sweepable wing mounted stores because a considerable amount of joints (with possible play) and bearings (with play and friction) is necessary but the problem is also present for fired wing airplanes. A major problem is the interpretation of linear ground resonance and flight flutter tests and their comparison with analytical predictions. Findings from ground resonance tests and flight flutter tests are presented and an explanation for these test results is given. Calculations with linear assumptions (parameter variations) were made and the method of harmonic balance for finding these parameters was applied. It is shown certain levels of excitation must be reached in order to make flight flutter tests reliable for establishing flutter clearance speeds.

**81-1624**

**Unsteady Aerodynamics of an Aerofoil at High Angle of Incidence Performing Various Linear Oscillations in a Uniform Stream**

C. Maresca, D.J. Favier, and J.M. Rebont
Institute de Mecanique des Fluides, Marseille, France, J. Amer. Helicopter Soc., 26 (2), pp 40-45 (April 1981) 10 figs, 1 table, 8 refs

Key Words: Airfoils, Rotary wings, Helicopters, Aerodynamic loads

During forward flight, the flow past the blade of a helicopter is complex owing to three-dimensional flow effects and unsteadiness. One can try to model such a flowfield by unsteady 2-D experiments. Most of the experimental and theoretical studies undertaken on this topic have tackled the problem by investigating aerofoils oscillating in pitch in steady flow, while little attention has been paid to effect of simultaneous oscillating velocity and oscillating incidence on stall. The aim of this paper is to present a new approach to the experimental study of a stalled rotor blade by investigating the unsteady aerodynamics of an aerofoil performing linear oscillations in a uniform stream. In particular, the case of oscillation with respect to the undisturbed flow involving simultaneously out-of-phase incidence and velocity variations is studied.

## MISSILES AND SPACECRAFT

(Also see Nos. 1666, 1672, 1716)

**81-1625**

**Fatigue Properties of Shuttle Thermal Protection System**

J. Sawyer and P. Cooper
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81899, 25 pp (Nov 1980)
N81-14346

Key Words: Shuttles (spacecraft), Heat shields, Fatigue life

Static and cyclic load tests were conducted to determine the static and fatigue strength of the RIS tile/SIP thermal protection system used on the orbiter of the space shuttle. The material systems investigated include the densified and undensified LI-900 tile system on the .40 cm thick SIP and the densified and undensified LI-2200 tile system on the .23 cm (.090 inch) thick SIP. The tests were conducted at room temperature with a fully reversed uniform cyclic loading at 1 Hertz. Cyclic loading causes a relatively large reduction in the stress level that each of the SIP/tile systems can withstand for a small number of cycles.

**81-1626**

**Nonlinear Dynamic Response of a Uni-Directional Model for the Tile/Pad Space Shuttle Thermal Protection System**

J. Housner, H. Edighoffer, and K. Park
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81901, 44 pp (Nov 1980)
N81-14345

Key Words: Shuttles (spacecraft), Heat shields, Periodic excitation, Random excitation, Resonant frequencies

A unidirectional analysis of the nonlinear dynamic behavior of the space shuttle tile/pad thermal protection system is developed and examined for imposed sinusoidal and random motions of the shuttle skin and/or applied tile pressure. The analysis accounts for the highly nonlinear stiffening hysteresis and viscous behavior of the pad which joins the tile to the shuttle skin. Where available, experimental data are used to confirm the validity of the analysis. Both analytical and experimental studies reveal that the system resonant frequency is very high for low amplitude oscillations but decreases rapidly to a minimum value with increasing amplitude.

**81-1627**
**Active Control of Dynamics Transfer Functions for a Flexible Spacecraft**
S.C. Garg
Toronto Univ., Ontario, Canada, Rept. No. UTIAS-239, CN-ISSN-0082-5255, 74 pp (Oct 1979)
N81-11103

Key Words: Spacecraft, Active control, Transfer functions

Flexible spacecraft consisting of a central rigid body and flexible appendages are examined. The dynamics of each appendage are discussed with emphasis on introducing transfer functions for point excitation in translation and rotation. The transfer matrix for the entire spacecraft is derived and details are given for pitch/twist attitude control of Hermes. The expressions are found useful in several respects, being devoid of modal truncation. A scheme is examined which modifies the spacecraft transfer function actively using acceleration feedback. Numerical results are obtained for Hermes, and then confirmed from an attitude control simulation incorporating control nonlinearities. Dynamics modification under ground control is also examined, including time delays, and an experiment of this type is proposed for Hermes.

**81-1628**
**Application of the Statistical Dynamic Method. Study of a Missile Nose-Cone in a Reverberating Acoustic Environment**
A. Bourgine
Royal Aircraft Establishment, Farnborough, England, RAE-LIB-Trans-1953 (Engl. transl. of "Application de la methode dynamique statistique." Presented at Conf., Paris, Feb 4, 1976, 18 pp (June 1980))
N81-15013

Key Words: Missiles, Composite materials, Acoustic excitation, Random excitation, Spectral energy distribution techniques, Statistical analysis

Theoretical results relating to the statistical dynamic description of a structure are discussed. The provisional general scheme for calculating the spectral distributions and overall levels of the vibrations induced in the structure by a diffused type of random acoustic field is presented. The results obtained from a series of experiments carried out on a specimen missile nose-cone made from a composite material are presented and compared with those obtained by theoretical calculation.

# BIOLOGICAL SYSTEMS

## HUMAN

**81-1629**
**An Analysis of Community Complaints to Air Force Aircraft Noise**
J. Mabry and R. Carey
MAN-Acoustics and Noise, Inc., Seattle, WA, Rept. No. AFAMRL-TR-80-88, 77 pp (Oct 1980)
AD-A092 923/2

Key Words: Aircraft noise, Human response

Community complaints to Air Force aircraft operations were studied for seven different Air Force Bases.

**81-1630**
**Aircraft Annoyance Evaluations Using Field and Laboratory Simulation Techniques**
G.W. Johnston and A.A. Haasz
Inst. for Aerospace Studies, Toronto Univ., Downsview, Ontario, UTIAS-248, 60 pp (Dec 1980)
N81-15580

Key Words: Aircraft noise, Human response, Laboratory test data, Field test data

A series of aircraft noise annoyance evaluation tests were performed under controlled conditions in a laboratory. Jurors drawn from nominal 30-35 NEF zones were exposed to aircraft noise events previously recorded near their homes in the vicinity of the Toronto International and Oshawa General Aviation Airports.

**81-1631**
**The Annoyance Caused by Noise Around Airports. Final Report**
NASA, Washington, D.C., Rept. No. NASA-TM-75784, 114 pp (July 1980), Transl. into English of "la Gene causee par le Bruit Autour des Aero-

ports," Centre Sci. et Tech. du Batiment, Paris, DGRST/CSTB-63-FR-138
N81-15579

Key Words: Aircraft noise, Human response

A comprehensive study of noise around selected airports in France was performed. By use of questionnaires, the degree of annoyance caused by aircraft noise was determined. Three approaches used in the study were: analytical study on the influence of noise on sleep; sociological study on the satisfaction of occupants of buildings which conform to laws which are supposed to guarantee sufficient comfort; and statistical study of correlations between external noises and psychological and pathological disturbances in residences.

**81-1632**
**Computer Simulations of Occupant Responses in Frontal Crashes Using CVS III**
B.J. Kelleher and M.J. Walsh
Calspan Advanced Tech. Ctr., Buffalo, NY, Rept. No. CALSPAN-6221-V-2, DOT-HS-805 632, 108 pp (Apr 1980)
PB81-136095

Key Words: Collision research (automotive), Human response, Safety restraint systems, Automobile seat belts, Seat belts, Crash cushions (safety restraint systems), Computerized simulation

Twelve computer simulations, utilizing the Calspan three-dimensional Crash Victim Simulator program, were executed. These computer simulations represent 50th percentile occupants, restrained with both three-point belt systems and air cushion restraint systems, seated in both the driver and right front passenger positions of a 1975 Volvo, at crash velocities of 30, 40 and 45 mph.

**81-1633**
**The Rating of Helicopter Noise: Development of a Proposed Impulse Correction**
B.F. Berry, H.C. Fuller, A.J. John, and D.W. Robinson
Acoustics Unit, Natl. Physical Lab., Teddington, England, Rept. No. NPL-AC-93, ISSN-0143-7143, 45 pp (Dec 1979)
N81-14792

Key Words: Helicopter noise, Human response

Efforts to the scale of effective perceived noise level (EPNL) to account for the subjective effects of impulsive helicopter noise are reported. Psychoacoustical studies of the annoyance of recorded and simulated helicopter noises are described and an objective descriptor of impulsiveness is developed. This descriptor forms the basis of a draft standard for an impulse correction to EPNL.

# MECHANICAL COMPONENTS

## ABSORBERS AND ISOLATORS

(Also see No. 1704)

**81-1634**
**Vibration Isolation of Stochastic Disturbed Systems by Means of Optimal Control (Schwingungsisolation stochastisch gestörter Systeme mit Methoden der optimalen Steuerung)**
B. Heimann, N. Model, and U. Koelle
Akedemie der Wissenschaften der DDR, Zentralinstitut f. Mathematik und Mechanik DDR 125 Erkner, Flakenstr. 28-31, Mech. Mach. Theory, 16 (2), pp 115-126 (1981) 8 figs, 10 refs
(In German)

Key Words: Vibration isolation, Stochastic processes, Optimum control theory, Motor vehicles

Vibration isolation problems of stochastically disturbed systems using optimal control are investigated. The determination of the optimum control and the feed-back is achieved by means of Bellman's functional equation. Using statistical linearization and dynamic programming, an iteration process for the determination of the control law and the system matrix is derived. The algorithm may be applied in the determination of vertical vibrations of motor vehicles caused by random street profile.

**81-1635**
**Floor and Fuel Vibration Isolation Systems for the Boeing Vertol Commercial Chinook**
R.A. Desjardins and V. Sankewitsch
Boeing Vertol Co., Philadelphia, PA, J. Amer. Helicopter Soc., 26 (2), pp 25-30 (Apr 1981) 19 figs, 4 refs

Key Words: Vibration isolation, Helicopters, Floors, Fuel tanks

A vibration isolation system is in development for the passenger cabin and the long-range fuel tanks of the Boeing commercial Chinook. The passenger floor is isolated from the airframe on a series of passive isolation units. The fuel tanks are also isolated so that their dynamic mass is effectively nulled at all fuel levels, thereby avoiding any deleterious effect on airframe natural frequency placement. Analyses, component tests, and an aircraft shake test were conducted to verify the effectiveness of the system. The aircraft test demonstrated that the floor isolation could lower the 0.15-g midcabin airframe vibration to an average of 0.05G on the passenger floor. The fuel isolation also was successful, maintaining an important airframe natural frequency within ± 0.2 Hz of its normal value for any fuel level from 0 to 100 percent.

**81-1636**

**Wave Power Absorption Characteristics of a Rocking Body**

H. Tanaka and M. Saito-o
Yokohama Natl. Univ., Tokiwadai 156, Hodogayaku, Yokohama, Japan, Bull. JSME, 24 (188), pp 370-373 (Feb 1981) 9 figs, 6 refs

Key Words: Energy absorption, Hydrodynamic excitation

The power characteristics and the efficiency of a wave power absorber, called Salters Duck, consisting of a rocking body and a hydro-static power conversion mechanism is examined. Efficiency of the wave power absorber depends both on the shape of front section of the body and on the load characteristics of the power taking off mechanism.

**81-1637**

**Bumpers with Energy-Absorbing Semi-Rigid Foam Material (Stossfänger mit energieabsorbierendem Halbhartschaumstoff)**

E. Ropte, E. Strickle, and O. Volkert
Blumenmorgen 16a, 4500 Osnabruck, ATZ, 83 (3), pp 97-100 (Mar 1981) 10 figs
(In German)

Key Words: Energy absorption, Bumpers, Foams

The energy of impact on plastic based bumpers is usually absorbed by a hydraulic device. In this paper, an energy-absorption system will be described, which contains a semi-rigid polyurethane foam. It has an ideal density of 100 g/l. Small-scale impact experiments yielded values for the calculation of bumper dimensions which could be directly applied to an automobile in practice. The measured compression properties were relatively independent of temperature.

**81-1638**

**Squeeze-Film Bearings as Vibration Isolators for Unbalanced Rigid Rotors**

E.J. Hahn
Univ. of New South Wales, Kensington, New South Wales, Australia 2033, ASLE Trans., 24 (2), pp 239-246 (Apr 1981) 5 figs, 13 refs

Key Words: Bearings, Squeeze film bearings, Roller bearings, Vibration isolators, Rigid rotors

Appropriately designed squeeze-film dampers can act as excellent vibration isolators for unbalanced rigid rotors. This paper presents the steady-state vibration amplitude and unbalance transmissibility data over a wide range of operating conditions for both unloaded vertical and centrally preloaded rigid rotors mounted in either one or two squeeze-film-supported rolling-element bearings. The use of this data to ensure effective vibration isolation consonant with acceptable rotor vibrations is discussed.

**81-1639**

**Dynamic Analysis of a Magnetically Suspended Energy Storage Wheel**

L.L. Bucciarelli and A. Rangarajan
Lincoln Lab., Mass. Inst. of Tech., Lexington, MA, Rept. No. DOE/ET-20279/102; CONF-801022-3, 8 pp (1980) (Presented at the Flywheel Technol. Symp., Scottsdale, AZ, Oct 26-30, 1980)
N81-11538

Key Words: Flywheels, Energy storage systems, Magnetic bearings

The results of an analysis conducted in support of the design of a l kWh flywheel fabricated and tested recently at the MIT Lincoln Laboratory are presented. The flywheel was a prototype of a 40 kWh residential unit to be used to store energy obtained from photovoltaic arrays. The l kWh system was designed to operate between 7500 and 15,000 rpm. The flywheel, made of seven 15 inch diameter steel disks, weighed about 400 pounds, and was suspended vertically by a flexible quill shaft from a set of six magnetic bearings. The magnetic bearings minimize frictional losses and require little maintenance over the design life of the system.

## TIRES AND WHEELS
(See No. 1585)

## BLADES
(Also see Nos. 1727, 1744)

**81-1640**

**A General Calculation Method for the Dynamic Response to Discrete Gust Distributions as Exemplified by the Rotorblade of a Wind Energy Converter**

D. Ludwig

Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt e.V., Goettingen, Fed. Rep. Germany, Rept. No. DFVLR-FB-80-12, 63 pp (Mar 1980)

N81-14408

(In German; English Summary)

Key Words: Blades, Rotors, Windmills, Wind-induced excitation

An analytical method to calculate the dynamic response of elastic structure to discrete gust distributions is presented. The formulation is based on the assumption that the modal parameters of the structure are known and can be received by eigenanalysis or ground vibration test. No restriction is made concerning the number of flapwise bending modes nor the distribution of discrete gusts. The generalized forces due to excitation and due to motion are approximated by means of the known exponential forms of Wagner's function and Kussner's function to get an analytical solution in the shortest possible computing time.

## BEARINGS
(Also see No. 1638)

**81-1641**

**Bearing Replacements for Turbomachinery**

D.J. Salamone

Centritech Corp., Houston, TX, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, April 7-9, 1981, pp 57-60, 6 figs, 4 refs

Key Words: Bearings, Turbomachinery, Stiffness coefficients, Steam turbines

This paper emphasizes the use of the critical speed map as a guide for the selection of replacement bearings to eliminate, or at least minimize, turbomachinery vibration problems. One of the most important considerations in bearing selection is the ratio of bearing stiffness to shaft stiffness. The rotor system dynamics cannot be truly optimized without a compatible stiffness match. Finally, it is pointed out that a wide range of bearing stiffness and damping characteristics are possible, depending on the particular type and geometry. An example is presented to illustrate the effectiveness of bearing redesign for a high speed steam turbine.

**81-1642**

**Methods for Computing Stiffness and Damping Properties of Main Propulsion Thrust Bearings**

L. Vassilopoulos

Maritech, Inc., Belmont, MA, Paper presented at the Society of Naval Architects and Marine Engineers, New England Section (Feb 24, 1981) 47 figs, 2 tables, 23 refs

Key Words: Tilting pad bearings, Thrust bearings, Bearings, Stiffness coefficients, Damping coefficients, Finite element technique, Finite difference theory

The study of longitudinal shaft vibrations of propulsion shafting systems requires knowledge of the thrust bearing stiffness and damping properties. The paper presents a step-by-step engineering procedure for determining these parameters using simplified structural models and elementary lubrication theory, but the utility of finite element and finite difference methods for more refined assessments is also mentioned. This paper deals with integral bearings of the hydrodynamic, tilting-pad type.

**81-1643**

**Self-Alignment Systems for Heavily Loaded, Compliant, Hydrodynamic Air Bearings**

B. Bhushan

Mechanical Tech. Inc., Latham, NY 12110, ASLE Trans., 24 (2), pp 247-256 (Apr 1981) 15 figs, 1 table, 3 refs

Key Words: Bearings, Journal bearings, Alignment

Internal and external self-alignment systems for compliant-foil journal bearings have been developed and tested at 35,000 rpm in ambient air. These systems have been shown to substantially improve the self-alignment capabilities of

the compliant-foil bearings. The standard bearings with center-split bump have a misaligned capacity of 0.07 degrees at 55 kPa and 0.03 degrees at 83 kPa.

**81-1644**

**Theory and Application of Multipocket Bearings for Optimum Turborotor Stability**

J.C. Nicholas and R.G. Kirk

Ingersoll-Rand Co., Phillipsburg, NJ 08865, ASLE Trans., 24 (2), pp 269-275 (Apr 1981) 10 figs, 2 tables, 17 refs

Key Words: Bearings, Multipocket bearings, Rotating structures, Vibration reduction, Subsynchronous vibration

Rotating machinery in the process industries and pipeline applications are many times designed with fixed-lobe-type bearing inserts. This paper summarizes a method of analysis which has been computer automated to allow the analysis and design optimization of multipocket bearings for application in turbomachinery. The general stability characteristics of multipocket bearing designs are compared to plain axial groove and multilobe bearings for specific examples. The analysis permitted the rapid design of a modified multipocket bearing which was successful in suppressing a high-amplitude subsynchronous vibration in two separate gas expanders under field operating conditions.

**81-1645**

**The Inclination of Cracking in the Peeling Failure of a Ball Bearing Steel and Its Relation to the Inclination of the Principal Residual Stress**

K. Maeda, N. Tsushima, and H. Muro

NTN Toyo Bearing Co., Ltd., 511 Kuwana, Japan, Wear, 65 (2), pp 175-190 (Dec 1980) 17 figs, 2 tables, 7 refs

Key Words: Bearings, Ball bearings, Fatigue life, Crack propagation

Peeling is a mode of surface fatigue failure which is produced by rolling contact under specific conditions. X-ray measurements of the residual stress on a peeled surface using the $0 \cdot 45^{\circ}$ method revealed that the stress values in the rolling direction and in the direction opposite to rolling were different. The inclination of cracking is explained by the residual tensile stress acting perpendicularly to the principal residual compressive stress.

**81-1646**

**The Sikorsky Elastomeric Rotor**

R. Rybicki

Sikorsky Aircraft, Stratford, CT, J. Amer. Helicopter Soc., 26 (1), pp 9-18 (Jan 1981) 22 figs, 3 tables, 2 refs

Key Words: Bearings, Elastomeric bearings, Rotors, Helicopters

The historical development of elastomeric rotor technology at Sikorsky from 1960 to 1980 is presented. This technology has permitted the development of several different rotor concepts employed on the H-53, BLACKHAWK, SEAHAWK, and S-76 helicopters which are discussed in detail. Design and analytic methodology used to support these programs is described. Testing and substantiation philosophy and methodology are also covered and some mistakes to avoid are highlighted. Problems encountered during the design, development, and substantiation of these systems are outlined as well as the solutions which were successfully employed. Elastomeric bearing manufacturing and quality control problems encountered are explained and guidelines for avoiding these problems are established.

## GEARS

**81-1647**

**Evaluation of Balancing Systems in Planetary Gears by Means of Dynamic Force Coefficients (Bewertung der Ausgleichssysteme in Planetengetrieben mit dynamischen Kraftbeiwerten)**

M. Kos

Maschinenbau-Fakultät Ljubljana, Yugoslavia, Konstruktion, 33 (3), pp 91-96 (Mar 1981) 9 figs, 1 table, 7 refs

(In German)

Key Words: Gears, Mechanical drives

In the description of balancing forces in planetary drives the dynamic coefficients contain dimensionless ratios of the drives, which eliminate masses and accelerations caused by defects. The dynamic force coefficients enable the analysis of the effect of the parameters and thus to determine the excitation of the structure. Five balancing systems are evaluated and the results are confirmed experimentally.

**81-1648**

**Analysis of Vibration of Bevel Gears**

S. Kiyono, Y. Fujii, and Y. Suzuki

Faculty of Engrg., Tohoku Univ., Aza-Aoba, Sendai, Japan, Bull. JSME, 24 (188), pp 441-446 (Feb 1981) 6 figs, 8 refs

Key Words: Gears, Bevel gears

Equation of motion for free vibrations of a pair of gears is derived in a general form. A vibration system of two-degrees-of-freedom which represents the fundamental characteristics of bevel gears is constructed mathematically. It is found from the analysis of the system that the fundamental characteristics of vibrations which distinguish bevel gears from spur and helical gears are caused by a change in the direction of the tooth-normal in tooth-meshing. The influences of parameters such as the contact ratio, stiffness of gear-carrying shafts and damping ratios on the band width of unstable regions of the vibration are also shown.

**81-1649**

**Dynamic Behavior of Straight Bevel Gear (2nd Report, Vibration of Bevel Gears on Rectangular-Coordinate)**

Y. Terauchi, M. Fujii, and H. Hoto

Faculty of Engrg., Hiroshima Univ., Hiroshima, Japan, Bull. JSME, 24 (188), pp 427-433 (Feb 1981) 18 figs, 2 tables, 2 refs

Key Words: Gears, Bevel gears, Vibration measurement, Experimental test data

Using an inductance type vibrometer for shaft, the displacement of bevel gears is measured on a rectangular-coordinate, and the results are discussed.

**81-1650**

**Parameter Excited Gear Vibrations. Part 4: The Effect of the Parameters on the Behavior of Helical Gears (Parametererregte Getriebeschwingungen. Teil 4: Einfluss von Parametern auf das Verhalten eines schrägverzahnten Getriebes)**

H. Peeken, C. Troeder, and G. Diekhans

Institut f. Maschinenelemente und Maschinengestaltung, Rheinisch-Westfalische Technische Hoschschule Aachen, VDI-Z, 122 (23/24), pp 1101-1113 (Dec 1980) 49 figs

(In German)

Key Words: Gears, Parametric excitation, Helical gears, Clearance effects, Error analysis

The vibration of a single step gear is investigated taking into account parametric excitation of straight and helical gears, axial and flexural degrees of freedom, gear clearance, and gear errors. The results are obtained numerically by means of a mathematical model. The load increment function and the resonance amplitudes can be described by means of generally valid characteristic factors, so that these results can be applied also to other drives. (See 81-1240 for Parts 1-3)

## COUPLINGS

**81-1651**

**Analytical Determinations of Dynamic Coefficients of Rubber Shaft Couplings (Analytische Bestimmung der dynamischen Kennwerte gummielastischer Wellenkupplungen)**

R. Röper and D. Japs

Lehrgebiet Maschinenelemente und Antriebstechnik an der Universitat Dortmund, Konstruktion, 33 (3), pp 113-116 (Mar 1981) 9 figs, 4 refs

(In German)

Key Words: Couplings, Elastomers, Stiffness coefficients, Damping coefficients

A relatively simple calculation of spring stiffness and damping properties of rubber couplings is presented. It is based on simple quasistatic measurements of the torque time slope of tightly fixed couplings which rotate in steps. In the calculation, the rubber couplings are regarded as a viscoelastic system taking its internal friction into consideration. The calculations -- even in the progressive range of coupling characterization -- agree well with experimental results.

**81-1652**

**An Experimental Investigation of the Effects of Aeroelastic Couplings on Aeromechanical Stability of a Hingeless Rotor Helicopter**

W.G. Bousman

Aeromechanics Lab., U.S. Army Res. and Tech. Labs., Moffett Field, CA, J. Amer. Helicopter Soc., 26 (1), pp 46-54 (Jan 1981) 10 figs, 5 tables, 10 refs

Key Words: Couplings, Aeroelasticity, Helicopters, Rotors, Stability

A 1.62-m diameter rotor model was used to investigate aeromechanical stability for ground and hover conditions and the

results were compared to theory. Configurations tested included: a nonmatched stiffness rotor as a baseline, the baseline rotor with negative pitch-lag coupling, the combination of negative pitch-lag coupling and structural flap-lag coupling on the baseline rotor, a matched stiffness rotor, and a matched stiffness rotor with negative pitch-lag coupling. The measured lead-lag regressing mode damping of the five configurations agreed well with theory, but only the matched stiffness case with negative pitch-lag coupling was able to stabilize the air resonance mode. Comparison of theory and experiment for the damping of the body showed significant differences that may be related to rotor inflow dynamics.

## FASTENERS

**81-1653**

**Damping Behaviour of Bolted Joints**

A. Shanker and N.K. Mital
Dept. of Mech. Engrg., Institute of Tech., Banaras Hindu Univ., Varanasi, India, Microtechnic, 4, pp 42-45 (1980) 12 figs, 1 table, 6 refs

Key Words: Joints (junctions), Bolts, Damping coefficients

The present work reports the experimental investigations carried out on the dynamic behavior of lap and butt joints under dry and lubricated conditions. It has been found that natural frequency of a joint remains practically unaffected by the bolt tightening torque, however lubricating the joints reduces the natural frequency of vibrations slightly. The damping ratio has been found to be dependent on the bolt tightening torque and joint conditions.

## LINKAGES

**81-1654**

**Dynamic Synthesis for Time Response of a Flexibly Coupled Slider Crank Mechanism with Pulse Loading**

J.M. Gulati and A.C. Rao
Dept. of Mech. Engrg., Government Engrg. College, Jabalpur (M.P.), India, J. Franklin Inst., 311 (3), pp 187-193 (Mar 1981) 3 figs, 12 refs

Key Words: Dynamic synthesis, Slider crank mechanism, Pulse excitation

Link mechanisms designed for time-dependent output on the assumption of uniform input velocity will not perform satisfactorily due to fluctuation of input velocity under the actual working conditions. Synthesis, taking the input velocity fluctuations into consideration, is very difficult. Incorporation of a flexible element between the input link and the drive-motor makes the synthesis very easy. Also, a mechanism used as a timing device, for example the one used for actuating a valve at specified timings, is subjected to pulse loading. A slider-crank mechanism subjected to such a pulse loading and flexibly coupled to a drive-motor is synthesized for position coordination in the present paper. A numerical example is included.

**81-1655**

**Oscillatory Distortions of Spatial Linkage Kinematic Characteristics**

J.I. Vulfson and V.S. Khorunghin
Techn. Sci., Leningrad Inst. for Textiles and Light Industry, Dept. of Theory Machines and Mechanisms, Gercen Str. 18, 191065, Leningrad, USSR, Mech. Mach. Theory, 16 (2), pp 137-146 (1981) 4 figs, 1 table, 6 refs

Key Words: Linkages, Coupled response, Torsional vibration, Flexural vibration

An analytical investigation method for coupled torsional and flexural vibrations of spatial crank-and-rocker mechanism output links is discussed. The dynamic model presented takes into account the dynamic response of a spatial coupler which is described with a system of differential equations with variable coefficients. By means of the method of the so-called "conventional oscillator" the formal frequency equation and the algorithm of a numerical-analytical solution of a system of differential equations is presented. The criterion of vibration "coupling" of flexural and torsional subsystems is offered.

## SEALS

(See No. 1582)

# STRUCTURAL COMPONENTS

## STRINGS AND ROPES

**81-1656**

**Simulation of the Dynamic Response of Transmission Lines in Strong Winds**

M.J. Matheson and J.D. Holmes

Dept. of Civil and Systems Engrg., James Cook Univ. of North Queensland, Townsville, Queensland, 4811, Australia, Engrg. Struc., 3 (2), pp 105-110 (Apr 1981) 5 figs, 3 tables, 13 refs

Key Words: Transmission lines, Wind-induced excitation, Monte Carlo method, Finite difference technique

A numerical simulation procedure for predicting the response of a single span transmission line to strong turbulent winds is described. The wind velocities are generated using a 'Monte Carlo' technique based on an inverse fast Fourier transform: the equations of motion of the line are then solved numerically using a finite difference method. Results obtained using the method were compared with those from linearized random vibration theory. Effects due to the mean swing angle of the line, and due to the excitation of an in-plane mode of vibration were apparent.

## CABLES

**81-1657**
**Natural Frequencies and Mode Shapes of Cables with Attached Masses**
S. Sergev and W.D. Iwan
Civil Engrg. Lab. (Navy), Port Hueneme, CA, Rept. No. CEL-TN-1583, 28 pp (Aug 1980)
AD-A092 960/4

Key Words: Cables (ropes), Mass-beam systems, Natural frequencies, Mode shapes, Computer programs

An algorithm has been developed to calculate mode shapes and natural frequencies of taut cables with attached masses. The transcendental equations of motion are solved by an iterative technique that allows accurate calculation of extremely high mode numbers. The algorithm has been implemented as a FORTRAN program primarily as a tool in determining drag coefficients of submerged strumming cables; however, any taut cable can be analyzed.

## BARS AND RODS

**81-1658**
**Forced Longitudinal Vibrations of a Rod by Taking into Account Amplitude Dependent Nonlinear Material Damping**
S. Katsaitis
Natl. Tech. Univ. of Athens, Athens, Greece, Forsch. Ing.-Wes., 47 (1), pp 25-32 (1981) 3 figs, 3 refs

Key Words: Rods, Longitudinal vibration, Material damping, Amplitude analysis

The behavior of a frequency independent linear and also of a frequency independent nonlinear material damping, whose nonlinearity depends on the maximum vibration distortion, is discussed for the case of forced longitudinal vibrations of rods. The theoretical results are compared with the results of a frequency dependent material damping. For an approximate solution of the nonlinear partial differential equations a proper mathematical method is introduced.

## BEAMS

(Also see Nos. 1765, 1783)

**81-1659**
**On the Response of a Timoshenko Beam under Initial Stress to a Moving Load**
B. Prasad
Scientific Res. Lab., Room S-2023, Ford Motor Co., 20000 Rotunda Dr., Dearborn, MI 48121, Intl. J. Engrg. Sci., 19 (5), pp 615-628 (1981) 4 figs, 3 tables, 19 refs

Key Words: Beams, Moving loads, Timoshenko theory, Railroad tracks

When an axial compressive force is present, the wavelength of the propagating free waves in a beam rapidly decreases. The conventional Euler-Bernoulli beam equations are often not adequate for determining dynamic behavior of the moving load on a beam supported on an elastic foundation when initial axial stress is present. Equations derived by Sun for the Timoshenko beam with initial axial stress (based on Trefftz's theory), form the basis of this investigation. Analytical solutions are presented for deformations of the beam both with and without damping. Expressions of the critical velocity as a function of initial axial stress and foundation modulus parameters, are obtained for the Timoshenko beam. Critical velocities of the Timoshenko beam, with and without axial stress, are compared with that obtained using Euler-Bernoulli beam formulation.

**81-1660**
**A New Technique for the Measurement of the Specific Damping Capacity of Beams in Flexure**
F.J. Guild and R.D. Adams

School of Engrg. Sci., Plymouth Polytechnic, Plymouth, UK, J. Phys. E: Sci. Instrum., 14 (3), pp 355-363 (Mar 1981) 12 figs, 2 tables, 4 refs

Key Words: Beams, Flexural vibration, Cracked media, Damping coefficients

Measurement of specific damping capacity may be an important method for the detection of small cracks in composite materials. Apparatus for the measurement of specific damping capacity of these lossy materials in free-free flexure without making attachments to the middle of the beam, has been developed. Comparative measurements were also made using a cantilever apparatus.

**81-1661**
**Analysis Method for Calculating Vibration Characteristics of Beams with Intermediate Supports**
H. Chung
Components Technology Div., Argonne Natl. Lab., Argonne, IL 60439, Nucl. Engrg. Des., 63 (1), pp 55-80 (Jan 1981) 7 figs, 4 tables, 14 refs

Key Words: Beams, Natural frequencies, Mode shapes, Fluid-induced excitation, Seismic excitation, Nuclear reactor components

Several reactor system components, such as fuel pins, heat exchanger tubes, control rods, and various instrumentation and shroud tubes, are beam-like components with intermediate supports along their length. Basic to any flow induced vibration or seismic analysis of these components is the need to determine their vibrational characteristics including natural frequencies and modes. This paper presents a simple solution method for calculating the natural frequencies and modes of beams with any of the classical boundary conditions and with unlimited intermediate supports.

**81-1662**
**Effects of Rotary Inertia and Shear on Natural Frequencies of Continuous Circular Curved Beams**
T.-M. Wang and M.P. Guilbert
Dept. of Civil Engrg., Univ. of New Hampshire, Durham, NH 03824, Intl. J. Solids Struct., 17 (3), pp 281-289 (1981) 4 figs, 10 refs

Key Words: Beams, Curved beams, Continuous beams, Natural frequencies, Rotatory inertia effects, Transverse shear deformation effects

The dynamic stiffness matrix for circular curved members of constant section has been derived for the determination of natural frequencies of continuous curved beams undergoing in-plane vibrations. An example of a two-span curved beam is given to illustrate the application of the proposed method and to show the effects of rotary inertia, shear and the central angle of the arc upon the natural frequencies of the beam.

**81-1663**
**The Normal Modes of Beam-Like Structures by a Lanczos-Stodola Method**
L.T. Niblett
Royal Aircraft Establishment, Farnborough, UK, Rept. No. RAE-TR-80058, RAE-STRUCT-BF/B/0832, 14 pp (May 1980)
N81-12470

Key Words: Beams, Cantilever beams, Mode shapes, Flexural vibration, Torsional vibration, Lanczos method, Stodola method

A method of finding the flexural and torsional normal modes of structures which have straight stiffness axes and which are mounted as cantilevers is given. The lanczos method of minimized iterations is used to obtain intermediate modes using integro-differential equations and the mass and stiffness distributions. The inertia matrix appropriate to the intermediate modes is tridiagonal and the stiffness matrix is unit. The dominant eigenvalues and vectors of the inertia matrix give good approximations to the graver normal models. Results of test calculations using a computer program which also allows for the presence of discrete masses are given.

## CYLINDERS
(Also see No. 1715)

**81-1664**
**Torsional Waves in an Axially Homogeneous Bimetallic Cylinder**
R.K. Kaul and R.P. Shaw
Dept. of Engrg. Science, Aerospace Engrg. and Nuclear Engrg., State Univ. of New York at Buffalo, Buffalo, NY 14214, Intl. J. Solids Struct., 17 (4), pp 379-394 (1981) 2 figs, 14 refs

Key Words: Cylinders, Torsional vibration

The dispersion spectrum is found for axially asymmetric torsional waves in an elastic, bimetallic rod with cylindrical

core and concentric outer casing. Plotting of the various branches of the spectrum is simplified by the presence of discrete invariant points which are independent of the material properties and through which the spectral lines must pass. The slope and curvature of the spectral lines at cut-off frequencies, the asymptotic approximations at high frequency, the non-existence of complex branches, the problem of co-existence and the concept of energy flow are also studied.

investigated. The starting point is consideration of the 3-D field equations of unsteady compressible magnetoaerodynamics. Using integral transforms, two closed-form solutions of the unsteady pressure loads are obtained, corresponding to two extreme ranges of Alfven numbers. At the end of the paper a simpler expression for the unsteady pressure loads is presented, which constitutes in fact a 3-D correction of one author's previous 2-D solution.

## COLUMNS

### 81-1665

**Dynamic Buckling of an Inelastic Column**

L.H.N. Lee
Dept. of Aerospace and Mech. Engrg., Univ. of Notre Dame, Notre Dame, IN 46556, Intl. J. Solids Struct., 17 (3), pp 271-279 (1981) 6 figs, 10 refs

Key Words: Columns, Dynamic buckling, Geometric effects, Bifurcation theory

A quasi-bifurcation theory, for systems subject to configuration-dependent forces, is employed to analyze the dynamic buckling behavior of an inelastic column hinged at both ends. Numerical results are presented and show that only certain eigenmodes of motion predominate at a time, as well as terminally depending on the nature of the time-dependent eigenvalues which, in turn, depend on the geometry, material properties and the loading history of the column.

## PANELS

### 81-1666

**Unsteady Pressure Loads for 3-D Flutter Calculation of Planar Configuration Panels in a Supersonic, Ionized Gas Flow**

L. Librescu
Dept. of Solid Mechanics, Materials and Struct., Tel Aviv Univ., Tel Aviv, Israel, Israel J. Tech., 18 (1-2), pp 37-46 (1980) 2 figs, 31 refs

Key Words: Panels, Rectangular panels, Flutter, Spacecraft

In this paper, the problem of the determination of unsteady pressure expressions, appropriate to the 3-D flutter analysis of rectangular panels in a supersonic ionized gas flow, is

### 81-1667

**Static and Dynamic Response of an Aluminum Alloy Panel Having a Central Opening with Combined In-Plane Biaxial Static Loading and Acoustic Excitation**

P. Datta and R. White
Inst. Sound Vib. Res., Southampton Univ., UK, Rept. No. ISVR-TR-103, 81 pp (Aug 1980)
N81-14353

Key Words: Panels, Plates, Acoustic excitation, Discontinuity-containing media, Dynamic tests, Periodic tests, Periodic excitation, Random excitation, Crack propagation

The static and dynamic response of an aluminum alloy panel, having a central opening, subjected to combined in-plane static tensile loading and acoustic excitation is described. The test specimens were tested in an acoustic tunnel to maximum sound pressure level of 145 dB with in-plane uniaxial and biaxial tensile loading. The local buckling of the free edge of the opening and the plate vibration characteristics were also investigated. The nonlinear behavior of the plate having a central opening was examined under sinusoidal and broad band random excitation. Crack propagation data from the high stress concentration zone at the tips of the opening under acoustic excitation are presented.

## PLATES

(Also see Nos. 1667, 1765)

### 81-1668

**Response of Rectangular Thick Plates to Moving Single Loads**

K. Shirakawa
Dept. of Mech. Engrg., Univ. of Osaka Prefecture, Mozu-Umemachi, Sakai, Osaka 591, Japan, Ingenieur-Archiv, 50 (3), pp 165-175 (1981) 6 figs, 10 refs

Key Words: Plates, Rectangular plates, Transverse shear deformation effects, Rotatory inertia effects, Moving loads

The response of a rectangular plate to a moving load is investigated. An improved plate theory which includes the effects of shear deformation and rotatory inertia as well as normal stress to the plate surface is introduced and the equation of motion in terms of single displacement is derived. Solutions are obtained by applying Fourier transforms. The effects of the approximation methods of the plate theory on the response of the displacment and the stress couples are examined with regard to the load velocity, plate dimensions, etc., in addition to the comparison with the results due to the classical plate theory.

**81-1669**

**Acoustic Radiation from an Impulsively Excited Elastic Plate**

S.S. Mackertich and S.I. Hayek

Lafayette College, Easton, PA 18042, J. Acoust. Soc. Amer., 69 (4), pp 1021-1028 (Apr 1981) 8 figs, 21 refs

Key Words: Plates, Submerged structures, Acoustic radiation, Pulse excitation

The acoustic radiated pressure time signature of a submerged elastic plate which is impulsively loaded is predicted analytically by use of integral transforms on time and space. The first arrival of the acoustic pulse at an observer point in the medium was shown to correspond to the acoustic time of arrival for the normal distance from the observer to the plate. After the first arrival, the time signature oscillates with decreasing amplitude with the passage of time. The period of oscillation was shown to increase with time and the decay rate was shown to decay inversely with elapsed time.

**81-1670**

**Analysis of Simply-Supported Orthotropic Plates Subject to Static and Dynamic Loads**

A.L. Dobyns

Boeing Military Airplane Co., Seattle, WA, AIAA J., 19 (5), pp 642-650 (May 1981) 13 figs, 1 table, 21 refs

Key Words: Plates, Orthotropic plates, Pulse excitation

Equations are presented for the analysis of simply-supported orthotropic plates subjected to static and dynamic loading conditions. Transient loading conditions considered include sine, rectangular, and triangular pulses, and pulses representative of high explosive blast and nuclear blast. These pulses can be applied as a uniform load over the panel, a concentrated load, a uniform load applied over a small rectangular area, and a cosine loading applied over a small rectangular area. A method for the analysis of low velocity impact is also presented.

**81-1671**

**Large Amplitude Vibration of Circular Plates Including Transverse Shear and Rotatory Inertia**

M. Sathyamoorthy

Dept. of Mech. and Indus. Engrg., Clarkson College of Tech., Potsdam, NY 13676, Intl. J. Solids Struct., 17 (4), pp 443-449 (1981) 6 figs, 1 table, 8 refs

Key Words: Plates, Circular plates, Flexural vibration, Transverse shear deformation effects, Rotatory inertia effects

This study is an analytical investigation of large amplitude flexural vibration of clamped circular plates with stress-free and immovable edges. The effects of transverse shear deformation and rotatory inertia are included in the governing equations. Solutions are formulated on the basis of Galerkin's method and the Runge-Kutta numerical procedure. An excellent agreement is found between the present results and those reported earlier for nonlinear static and dynamic cases.

**81-1672**

**Finite Element Structural Model of a Large, Thin, Completely Free, Flat Plate**

S. Joshi and N. Groom

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-81887, 21 pp (Sept 1980)

N81-13992

Key Words: Plates, Mode shapes, Natural frequencies, Finite element technique, Spacecraft

A finite element structural model of a 30.48 m x 30.48 m x 2.54 mm completely free aluminum plate is described and modal frequencies and mode shape data for the first 44 modes are presented. An explanation of the procedure for using the data is also presented. The model should prove useful for the investigation of controller design approaches for large flexible space structures.

## SHELLS

**81-1673**

**Dynamic Analyses of Liquid Storage Tanks**

M.A. Haroun

Earthquake Engrg. Res. Lab., California Inst. Tech., Pasadena, CA, Rept. No. EERL-80-04, NSF/RA-800217, 292 pp (Feb 1980)
PB81-123275

Key Words: Storage tanks, Tanks (containers), Shells, Cylindrical shells, Fluid-filled containers, Earthquake resistant design, Earthquake response

The dynamic behavior of cylindrical liquid storage tanks was investigated to improve their ability to resist earthquakes. The study comprised three phases: a theoretical treatment of the liquid-shell system; an investigation of the dynamic characteristics of full-scale tanks; and development of an improved design procedure based on an approximate analysis. Natural vibration frequencies and associated mode shapes were found.

**81-1674**
**Evaluation of Liquid Dynamic Loads in Slack LNG Cargo Tanks**
P.A. Cox, E.B. Bowles, and R.L. Bass
Southwest Res. Inst., San Antonio, TX, Rept. No. SWRI-SR-1251, SSC-297, 201 pp (May 1980)
AD-A091 153/7

Key Words: Tanks (containers), Fluid-filled containers, Sloshing, Design techniques

This report provides an evaluation of dynamic sloshing loads in slack LNG cargo tanks. A comprehensive review of worldwide scale model sloshing data is presented. The data are reduced to a common format for the purposes of defining design load coefficients. LNG tank structural details are reviewed with emphasis placed on defining unique design features which must be considered in designing LNG tanks to withstand dynamic sloshing loads. Additional scale model laboratory experiments are conducted to supplement the available model sloshing data. Experiments are conducted in combined degrees of freedom to establish the potential for multi-degree of freedom excitation for augmenting dynamic sloshing loads. Experiments are also conducted to establish the sloshing dynamic pressure-time histories which are necessary for structural response analysis. Experiments are also conducted on representative segments of a full-scale LNG ship tank structure which is loaded with a typical full-scale dynamic sloshing pressure as predicted from the model results. Analytical studies are undertaken to provide techniques for determining wall structural response to dynamic slosh loads. Finally, design methodology is presented for membrane and semi-membrane tanks, gravity tanks, and pressure tanks whereby the design procedures sequences from comparing resonant sloshing periods to ship periods, defining the design loads, and designing the tank structures affected by dynamic slosh loads by delineated procedures which vary with tank type.

**81-1675**
**Calculation of the Free Oscillations of a Heavy Incompressible Fluid in an Axially Symmetrical Vessel by Means of Panel Methods**
U. Schilling and J. Siekmann
Universität Essen - Gesamthochschule, Essen, W. Germany, Israel J. Tech., 18 (1-2), pp 13-20 (1980) 5 figs, 10 refs

Key Words: Fluids, Fluid-filled containers, Sloshing

In this paper the irrotational motion of a heavy ideal and incompressible fluid which partially fills an axisymmetric tank has been investigated. The axis of the container is supposed to be parallel to the direction of gravity. Under the assumptions made the potential flow of the liquid is governed by the Laplace equation, the zero normal velocity condition at the impermeable wall, and the conditions at the free liquid surface.

**81-1676**
**Response of a Point Excited Infinitely Long Cylindrical Shell Immersed in an Acoustic Medium**
W. Vogel and D. Feit
David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD, Rept. No. DTNSRDC-80/061, 62 pp (Nov 1980)
AD-A091 947/2

Key Words: Shells, Cylindrical shells, Fluid-induced excitation, Point source excitation

The velocity distribution of a point excited, infinitely long, thin cylindrical shell immersed in an acoustic medium is considered. The problem is analyzed by applying integral transform techniques; a solution is then obtained by evaluating the inverse transform integrals numerically. Examples are presented to illustrate the effect of fluid loading on the vibrational behavior of a point excited cylindrical shell. In addition, results are compared with those of a point excited plate with and without fluid loading.

**81-1677**
**Experiments on the Dynamic Behavior of Fluid-Coupled Concentric Cylinders**
M.L. Chu and S. Brown
Univ. of Akron, Akron, OH 44325, Exptl. Mechanics, 21 (4), pp 129-137 (Apr 1981) 12 figs, 3 tables, 26 refs

Key Words: Shells, Cylindrical shells, Concentric structures, Fluid couplings, Interaction: solid-fluid, Nuclear reactor components, Vibration tests

This research program was aimed at investigating experimentally solid-fluid interaction during vibrations of concentric cylinders coupled with fluid in the annular region, and to obtain 'benchmarks' for analytical modeling.

**81-1678**

**Analysis of a Cylindrical Shell Vibrating in a Cylindrical Fluid Region**

H. Chung, P. Turula, T.M. Mulcahy, and J.A. Jendrzejczyk

Components Technology Div., Argonne Natl. Lab., Argonne, IL 60439, Nucl. Engrg. Des., 63 (1), pp 109-120 (Jan 1981) 11 figs, 4 tables, 10 refs

Key Words: Shells, Cylindrical shells, Linings, Nuclear reactor components, Natural frequencies, Mode shapes, Harmonic response, Computer programs

Analytical and experimental methods are presented for evaluating the vibration characteristics of cylindrical shells such as the thermal liner of the Fast Flux Test Facility reactor vessel. The NASTRAN computer program is used to calculate the natural frequencies, mode shapes, and response to a harmonic loading of a thin, circular cylindrical shell situated inside a fluid-filled rigid circular cylinder. Solutions in a vacuum are verified with an exact solution method and the SAP IV computer code. Comparisons between analysis and experiment are made, and the accuracy and utility of the fluid-solid interaction package of NASTRAN is assessed.

**81-1679**

**Dynamic Propagation of Longitudinal Cracks in a Pressurized Cylindrical Shell Due to Ductile Failure**

H.-C. Lin

Components Technology Div., Argonne Natl. Lab., Argonne, IL 60439, Nucl. Engrg. Des., 63 (1), pp 137-142 (Jan 1981) 5 figs, 22 refs

Key Words: Shells, Cylindrical shells, Nuclear reactor components, Crack propagation

The dynamic motion of a longitudinal through-crack along a pressurized pipe or shell structure was studied. The endochronic theory of viscoplasticity were used for the description of inelastic material behavior. Numerical examples were given for a suddenly introduced axial through-crack in the wall of a pressurized pipe which is allowed to propagate according to Weiss - Sengupta notch-strength theory of ductile static fracture. Crack tip position and crack opening displacement profile were obtained at various times. No crack arrest was observed in the example due to the assumption of a constant internal pressure.

**81-1680**

**Transient Responses of a Cantilever Cylindrical Shell Subjected to Impulsive Loads on Its Free Edge: The Influences of Rotatory Inertia and Transverse Shear Deformation**

S. Ujihashi, T. Okazaki, H. Matsumoto, and I. Nakahara

Faculty of Engrg., Tokyo Inst. Tech., 2-12-1, Oh-okayama, Meguro-ku, Tokyo, Bull. JSME, 24 (188), pp 295-304 (Feb 1981) 13 figs, 4 tables, 17 refs

Key Words: Shells, Cylindrical shells, Cantilever beams, Pulse excitation, Transverse shear deformation effects, Rotatory inertia effects

In this paper, the transient responses of a cantilever circular cylindrical shell subjected to impulsive loads on its free edge are analyzed on the basis of an improved dynamic shell theory, namely, Mirsky - Hermann's theory, considering the influences of the rotatory inertia and the transverse shear deformation by the use of Laplace transformation. The numerical results are compared with those previously obtained by the author via Flugge's classical dynamic theory.

**81-1681**

**Vibration of a Materially Monoclinic, Thick-Wall Circular Cylindrical Shell**

M.E. Vanderpool and C.W. Bert

General Dynamics Corp., Fort Worth, TX, AIAA J., 19 (5), pp 634-641 (May 1981) 2 figs, 3 tables, 24 refs

Key Words: Shells, Circular shells, Cylindrical shells

The resonant vibration frequencies of a fiber-reinforced, thick-wall, circular-cylindrical shell of finite length which is materially monoclinic are analyzed. The degree of material anisotropy precludes a closed-form solution and so an iterative, yet exact, method is used. The analytical method is validated by comparison of results with previously published results for a homogeneous, isotropic thin shell, and an

orthogonally stiffened-thin shell modeled as orthotropic. Results for a materially monoclinic, thick-wall shell with free-free end conditions are compared with experimental results obtained by the present investigators.

### 81-1682
**Moving Load on a Two-Layered Cylindrical Shell with Imperfect Bonding**

S. Chonan
Dept. of Mech. Engrg., Tohoku Univ., Sendai, Japan,
J. Acoust. Soc. Amer., 69 (4), pp 1015-1020 (Apr 1981) 10 figs, 7 refs

Key Words: Shells, Cylindrical shells, Layered materials, Moving loads

This paper reports on the response to a moving ring load of an infinitely long two-layered cylindrical shell with a flexible bond at the interface. Both the dissimilar shells are assumed to bend according to a thick-shell theory. Solutions are obtained by the Fourier transform method with respect to an axial space variable. Numerical results are given for a laminated shell composed of inner hard rubber and outer duralumin shells. The load speed which generates a resonance in the system is calculated. Further, the displacement and the moment in each shell are evaluated for a range of parameters. The results are also compared with those from the classical thin-shell theory.

### 81-1683
**Free Vibrations of Orthotropic Spherical Shells**

V.C.M. de Souza and J.G.A. Croll
Proconsulte Construcoes Ltd., Rio de Janeiro, Brazil,
Engrg. Struc., 3 (2), pp 71-84 (Apr 1981) 9 figs, 7 tables, 21 refs

Key Words: Shells, Spherical shells, Equations of motion, Stiffness coefficients

The equations of motion for the free vibrations of orthotropically stiffened open spherical shells are developed and solved using a suitable finite difference model. Variations in both flexural and extensional orthotropic stiffness properties are investigated by means of carefully selected parametric studies. A systematic examination of the contribution to strain energy in each mode, arising from the various components of orthotropic shell stiffness, is shown to assist the interpretation of the effects of orthotropic stiffness changes, and to allow prediction of approximate frequency spectra. Based on the analysis of a related isotropic spherical shell it is shown how a modified form of Rayleigh's method provides approximations of frequency spectra sufficiently accurate to assist the conceptual dynamic design process.

### 81-1684
**Solutions of Some Stability Problems in the Theory of Geometrically Non-Linear Shells**

D. Shilkrut
Dept. of Mech. Engrg., Ben Gurion Univ. of the Negev, Be'er Sheva, Israel,
Israel J. Tech., 18 (1-2), pp 76-83 (1980) 16 figs, 2 tables, 32 refs

Key Words: Shells, Spherical shells, Stability

This paper presents a survey of some results of research performed by the author and his students in the area of the theory of geometrically non-linear spherical shells. The spherical shells, together with the cylindrical shells, are one of the principal models for the study of the stability of non-linear shells. The overwhelming majority of the effects that are observed in the spherical shells are typical also for shells of arbitrary shapes.

## RINGS

### 81-1685
**Vibration Characteristics of a Steadily Rotating Slender Ring**

F. Lallman
NASA Langley Res. Ctr., Hampton, VA,
Rept. No. NASA-TP-1775, 100 pp (Dec 1980)
N81-14343

Key Words: Rings, Rotating structures, Vibration response

Partial differential equations are derived to describe the structural vibrations of a uniform homogeneous ring which is very flexible because the radius is very large compared with the cross sectional dimensions. Elementary beam theory is used and small deflections are assumed in the derivation. Four sets of structural modes are examined: bending and compression modes in the plane of the ring; bending modes perpendicular to the plane of the ring; and twisting modes about the centroid of the ring cross section. Spatial and temporal characteristics of these modes, presented in terms of vibration frequencies and ratios between vibration amplitudes, are demonstrated in several figures. Given a sufficiently high rotational rate, the dynamics of the ring approach those of a vibrating string. In this case, the velocity

of traveling wave in the material of the ring approaches in velocity of the material relative to inertial space, resulting in structural modes which are almost stationary in space.

## PIPES AND TUBES

(Also see Nos. 1594, 1796, 1797, 1798)

**81-1686**

**Piping Vibration and Stress**

J.C. Wachel

Appl. Physics Div., Southwest Res. Inst., San Antonio, TX, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, April 7-9, 1981, pp 1-9, 6 figs, 2 tables, 2 refs

Key Words: Piping systems, Geometric effects, Fluid-induced excitation, Vibration control

The effect of piping design on pulsation-induced mechanical vibrations is discussed along with associated stresses.

**81-1687**

**Vibration Problems in Pipe Systems: Causes, Consequences and Abatement**

J.P.M. Smeulers

Technische Physische Dienst TNO-TH, Delft, The Netherlands, Vibration Tech., Ned. Akoestisch Genootschap, pp 36-45 (Jan 1980)

N81-15402

Key Words: Pipelines, Pulse excitation, Computer programs, Finite element technique

Pipe systems were investigated on pulsations using the analog simulator PULSIM. A finite element program was used to examine the response of the pipe system on the pulsation induced vibration forces.

**81-1688**

**Frequency Response Analysis of Fluid Control Systems for Parabolic-Trough Solar Collectors**

R. Schindwolf

Sandia Natl. Lab., Albuquerque, NM, ASME Paper No. 80-WA/Sol-15

Key Words: Solar cells, Pipelines, Frequency response

This paper derives a linearized steady-state frequency response for parabolic-trough collectors and for connecting piping that can be used in standard gain-phase analyses to evaluate system stability and closed-loop frequency response. The frequency-response characteristics of a typical collector string and piping are used in a gain-phase analysis to get some insight into the effect on system stability of various system parameters such as controller gain, sensor and controller-time constants, and sensor location.

**81-1689**

**Thermal Onset of Oscillation in a Pipe Containing Heat Sources**

H. Nomoto and Y. Katto

Turbine Works, Toshiba Corp., 2-4 Suehiro-cho, Tsurumi, Yokohama, Japan, Bull. JSME, 24 (188), pp 388-395 (Feb 1981) 14 figs, 15 refs

Key Words: Pipes (tubes), Thermal excitation, Self-excited vibrations

A self-excited oscillation in a pipe containing heat sources has been studied both experimentally and theoretically. Various parameters, total pipe length, relative location of heat sources, configuration of heat sources and so on have been clarified through quantitative experiments concerning the onset of an oscillation with three kinds of gases, air, helium, and carbon dioxide. A new type of critical curve with pressure and temperature difference between the heat sources is presented in this paper.

## DUCTS

**81-1690**

**Error Analysis of Spectral Estimates with Application to the Measurement of Acoustic Parameters Using Random Sound Fields in Ducts**

A.F. Seybert and B. Soenarko

Dept. of Mech. Engrg., Univ. of Kentucky, Lexington, KY 40506, J. Acoust. Soc. Amer., 69 (4), pp 1190-1199 (Apr 1981) 10 figs, 12 refs

Key Words: Ducts, Error analysis, Measurement techniques, Acoustic properties, Acoustic spectra, Spectral energy distribution techniques

Several methods have been proposed using multiple-point pressure measurement of random sound fields in ducts to determine acoustic properties of materials and systems. This paper presents an error analysis of the spectral estimates used in these techniques. Expressions for the normal acoustic absorption coefficient and impedance are derived for a random sound field in a duct. Theory is developed to determine the bias and random errors in estimating the spectral density function for plane-wave propagation in the duct. A bivariate stochastic process has been employed to model the acoustic system. Experimental and theoretical calculations show that minimum-bias error can be achieved by using a small bandwidth in estimating the spectra and by locating the microphones close to the sample. Furthermore, random error can be minimized by maintaining a high coherence between microphone signals.

## BUILDING COMPONENTS

**81-1691**

**A Linearization Technique for the Dynamic Response of Nonlinear Continua**

C.M. Krousgrill, Jr.

California Inst. Tech., Ph.D. Thesis, 133 pp (1981)
UM-8105124

Key Words: Structural members, Equivalent linearization method, Harmonic excitation, Random excitation, Beams, Plates

The efforts of this dissertation are directed toward the development of a technique for understanding the dynamic response of structural elements governed by nonlinear partial differential equations. This technique is based on the concepts of the equivalent linearization method which relies on obtaining an optimal linear set of equations to model the original nonlinear set. In this method, the linearization is performed at the continuum level. At this level, the equivalent linear stiffness and damping parameters are physically realizable and are defined in such a way that the method can be easily incorporated into finite element computer codes. Three different approaches to the method are taken with each approach based on the minimization of a distinct difference between the nonlinear system and its linear replacement. Existence and uniqueness properties of the minimization solutions are established.

**81-1692**

**Dynamic Stability of Structural Elements Subjected to Step Loads**

C.A. Lazopoulos

Georgia Inst. Tech., Ph.D. Thesis, 186 pp (1980)
UM 8106073

Key Words: Structural members, Step response, Dynamic buckling

The purpose of the present work is to investigate the concept of dynamic stability of structural elements subjected to step-loads and to develop the related criteria and estimates for finding critical conditions.

# ELECTRIC COMPONENTS

## MOTORS

**81-1693**

**A Case Study of Mechanical and Magnetic Interaction in a Two-Pole Induction Motor**

J.D. Halloran

Turbocompressor Div., Joy Machinery Co., Buffalo, NY 14227, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, April 7-9, 1981, pp 61-67, 5 figs, 1 table, 4 refs

Key Words: Motors, Induction motors, Synchronous vibration

Vibration data from a particular two-pole induction motor are presented and discussed. This motor showed significant levels of both rotor synchronous and line synchronous vibrations. Interpretations are made of the motions involved in this mechanical and magnetic interaction. Conclusions are derived in the form of the necessary test methods which would have defined the existence and extent of this vibration problem during acceptance testing at the vendor's plant.

**81-1694**

**Attempting to Recover an Electric Motor**

K.J. Laurent

Shell Oil Co., Norco, LA, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, April 7-9, 1981, pp 69-72, 3 figs

Key Words: Motors, Bearings, Alignment, Loosening, Stability

This paper presents a case study of the problems encountered in attempting to recover a large electric motor after a severe bearing failure. The problems include internal misalignment, mechanical looseness and rotor instability. The techniques used in data acquisition and analysis and the step by step approach toward resolving the problems are discussed and documented in detail.

# DYNAMIC ENVIRONMENT

## ACOUSTIC EXCITATION

(Also see Nos. 1611, 1612, 1613, 1614, 1633)

**81-1695**

**Acoustic Radiation Force on a Solid Elastic Sphere in a Spherical Wave Field**

T. Hasegawa, M. Ochi, and K. Matsuzawa
Faculty of Science, Ehime Univ., Matsuyama, Ehime 790, Japan, J. Acoust. Soc. Amer., 69 (4), pp 937-942 (Apr 1981) 9 figs, 14 refs

Key Words: Sound waves, Elastic waves, Wave propagation, Sound pressures, Spheres

The acoustic radiation force on a homogeneous solid sphere placed freely in a spherical sound field in an inviscid fluid is calculated; the effect of the elasticity of the sphere material is studied. Calculated results are presented for a variety of solid spheres in water. Quite distinctive resonance departures from the rigid sphere solution are found.

**81-1696**

**Uniformly Accurate Description of Finite Amplitude Sound Radiation from a Harmonically Vibrating Planar Boundary**

J.H. Ginsberg
School of Mech. Engrg., Georgia Inst. Tech., Atlanta, GA 30332, J. Acoust. Soc. Amer., 69 (4), pp 929-936 (Apr 1981) 5 figs, 22 refs

Key Words: Sound waves, Elastic waves, Harmonic excitation

The velocity potential for the two-dimensional, finite amplitude acoustic waves induced by harmonic excitation on a region in an infinite baffle was obtained earlier. That analysis, which represented the response in terms of a continuous spectrum of wavenumbers parallel to the boundary, was valid only for limited distances from the boundary. The current analysis employs the perturbation method of renormalization to derive expressions for the pressure and particle velocity that are uniformly accurate up to the location where a shock forms. The response consists of radiative and evanescent waves, with nonlinearity being significant only for the former. The solution is described as inversions of Fourier cosine transforms which feature a straining transformation of the space-time coordinates. A quantitative example for the case of an intense high-frequency excitation is shown to lead to a sound beam in which the nonlinear distortion is asymmetrical between the compression and rarefaction phases.

**81-1697**

**Scattering of Transient Acoustic Waves by an Inhomogeneous Obstacle**

G.C. Herman
Dept. Electrical Engrg., Lab Electromagnetic Res., Delft Univ. Tech., P.O. Box 5031, 2600 GA Delft, The Netherlands, J. Acoust. Soc. Amer., 69 (4), pp 909-915 (Apr 1981) 8 figs, 1 table, 11 refs

Key Words: Sound waves, Elastic waves, Wave diffraction

A method is described to compute the scattering of transient, scalar, acoustic waves by arbitrarily shaped, three-dimensional, inhomogeneous, penetrable objects of bounded extent. The problem is formulated in terms of a volume-integral equation over the interior of the scatterer. This integral equation is solved numerically by the marching-on-in-time method. Comparison is made with analytical results for a spherical, homogeneous scatterer, while some numerical results for scatterers of different shapes are presented.

**81-1698**

**Reflection and Transmission of Acoustic Waves by the Periodic Interface Between a Solid and a Fluid**

J.T. Fokkema
Dept. Electrical Engrg., Delft Univ. Tech., Delft, The Netherlands, Wave Motion, 3 (2), pp 145-157 (Apr 1981) 8 figs, 4 tables, 9 refs

Key Words: Sound waves, Elastic waves, Sound reflection, Sound transmission, Interface: solid-fluid

The redistribution of acoustic energy incident on a spatially periodic interface between a solid and a fluid is investigated theoretically. The main tools in the analysis are the elastodynamic Green-type integral relations. One of these relations is a vectorial integral equation from which the elastodynamic field quantities can be determined. The solid-medium part of it is identical to the case of the interface between two solids investigated in a previous paper, the fluid-medium part, however, needs reformulation. Numerical results are presented for the sinusoidal interface between granite and sea water. The computations have been carried out for four different heights of the periodic profile (the plane interface included), a single frequency of operation and the three types of excitation.

## 81-1699

### Dynamic Stress Concentrations of Cylindrical Cavities with Sharp and Smooth Boundaries: I. SH Waves

D.J.N. Wall, V.V. Varadan, and V.K. Varadan
Wave Propagation Group, Dept. Engrg. Mechanics, Ohio State Univ., Columbus, OH 43210, Wave Motion, 3 (2), pp 203-213 (Apr 1981) 11 figs, 1 table, 11 refs

Key Words: Shear waves, Elastic waves, Wave diffraction, Cavity-containing media, Dynamic stress concentration

This paper demonstrates a method for the calculation of the dynamic stress concentration factor when a time-harmonic elastic wave is incident upon a cylindrical cavity of arbitrary cross-section. A procedure which enables cross-sectional shapes with corners to be examined is discussed. It is shown that for scatterers with corners a piecewise basis must be chosen to represent the surface displacement. The algebraic system of equations obtained from the integral equations and appropriate constraints on the basis representation are then sufficient to determine the stress concentration uniquely. Results are given for cylindrical cavities with square, elliptic and intersecting circular cross sections for SH wave incidence.

## 81-1700

### Propagation of Plane, Cylindrical and Spherical Finite Amplitude Waves

D.H. Trivett and A.L. Van Buren
Underwater Sound Reference Detachment, Naval Res. Lab., P.O. Box 8337, Orlando, FL 32856, J. Acoust. Soc. Amer., 69 (4), pp 943-949 (Apr 1981) 11 figs, 2 tables, 14 refs

Key Words: Wave propagation, Spherical waves, Frequency domain method

A numerical solution to the generalized Burgers' radial wave equation has been developed; it allows one to calculate stepwise the harmonic content of a finite amplitude wave in the frequency domain for the case of plane, cylindrical, or spherical geometry. The finite amplitude wave may have any initial harmonic content with arbitrary phase, and the absorption coefficient of each harmonic is independently adjustable. Remaining in the frequency domain allows a much larger step than conventional algorithms, which alternate between the time and frequency domains. The algorithm is used to investigate the effect of a large second-harmonic absorption coefficient on saturation suppression and to investigate the farfield behavior of spherical waves.

## 81-1701

### Resonance Phenomena of Lamb Waves Scattering by a Finite Crack in a Solid Layer

S.I. Rokhlin
Dept. of Materials Engrg., Ben-Gurion Univ. of the Negev, Beer Sheva, Israel, J. Acoust. Soc. Amer., 69 (4), pp 922-928 (Apr 1981) 9 figs, 8 refs

Key Words: Waveguides, Lamb waves, Wave diffraction, Cracked media, Acoustic resonance

The paper is concerned with diffraction of Lamb waves by a finite crack, parallel to surfaces, in an elastic layer. The solution is constructed by the method of multiple diffractions at the edges of the crack. It is shown that the solution is identical with the solution obtained previously by the generalized Wiener-Hopf method. The resonance phenomena associated with the diffraction of Lamb waves by a finite crack are analyzed. The contribution of the different Lamb waves, generated in the crack zone, to the transmitted and reflected fields, is considered. An approximation of the solution, associated with incorporation of a finite number of Lamb waves, excited in the region of the layer occupied by the crack is discussed. Simple approximate equations are presented for resonance frequencies.

## 81-1702

### Calibration Technique for Acoustic Scattering Measurements

L.R. Dragonette, S.K. Numrich, and L.J. Frank
Acoustics Div., Naval Res. Lab., Washington, D.C. 20375, J. Acoust. Soc. Amer., 69 (4), pp 1186-1189 (Apr 1981) 5 figs, 21 refs

Key Words: Underwater sound, Acoustic scattering, Measurement techniques, Calibrating

Tungsten carbide spheres are used as calibration targets in laboratory acoustic scattering measurements. Though the steady-state response of any metal sphere in water greatly differs from a rigid body return, over almost the entire frequency spectrum, the rigid body and elastic returns can be separated in a short pulse, broadband experiment. This rigid body echo can then be used as a reference to normalize the scattering returns from targets of interest.

**81-1703**
**Shadowing by Finite Noise Barriers**
H. Medwin
Physics and Chemistry Dept., Naval Postgraduate School, Monterey, CA 93940, J. Acoust. Soc. Amer., 69 (4), pp 1060-1064 (Apr 1981) 9 figs, 15 refs

Key Words: Noise shielding, Noise reduction, Prediction techniques

A technique is described for calculating the acoustical shadowing due to finite barriers. The method is an extension of the Biot - Tolstoy rigorous closed-form impulse solution for diffraction of point-source radiation by an infinite rigid wedge. By discrete Fourier transformation, spectral predictions are obtained which are closer to experimental results than previous schemes for infinite barriers. Furthermore, the limitations of the Kirchoff Assumption are avoided, so that accurate predictions can be made for complicated finite barriers. Comparisons of theory and experiment are shown.

**81-1704**
**Reduction of Sound Emission in a Hollow Sectional Steel by Damping (Verminderung der Schallabstrahlung eines Hohlprofilstahls durch Bedämpfung)**
G. Rau
Zentralinstitut f. Arbeitsschutz, Dresden Leitstelle f. Larm- und Schwingungsabwehr, German Dem. Rep., Maschinenbautechnik, 29 (12), pp 564-565 (Dec 1980) 4 figs, 1 table, 4 refs
(In German)

Key Words: Noise reduction, Sound power levels, Steel, Damping materials, Foams

This article deals with measurements of the sound power level referred to force of a hollow sectional steel damped diversely. Reduction of sound emission depends upon mass and adherence of used damping material.

## SHOCK EXCITATION

**81-1705**
**Inelastic Torsional Response of Structures Subjected to Earthquake Ground Motions**
Y. Yamazaki
Earthquake Engrg. Res. Ctr., California Univ., Berkeley, CA, Rept. No. UCB/EERC-80/07, NSF/RA-800193, 165 pp (Apr 1980)
PB81-122327

Key Words: Seismic excitation, Earthquake response, Torsional response

The objectives of this paper are to identify the basic parameters which control the earthquake response of torsionally coupled systems composed of resisting elements providing force interaction during yielding; to clarify differences in response between systems subjected to single-component ground motion and systems subjected to double-component ground motion; to clarify differences in response among an elastic system, an elasto-plastic system without force interaction, and an elasto-plastic system with force interaction; and to evaluate the effects of magnitude of eccentricity and magnitudes of yield shear forces on the response of elasto-plastic systems with force interaction. A single-story structure with a rectangular deck and four resisting elements was used to examine these objectives.

**81-1706**
**Seismic Safety Margins Research Program, Phase 1. Project 5. Structural Sub-System Response: Subsystem Response Review**
J. Fogelquist, M. Kaul, R. Koppe, S.W. Tagart, Jr., H. Thailer, and R. Uffer
Nuclear Services Corp., Campbell, CA, UCRL-15215, 107 pp (Mar 1980)
N81-15158

Key Words: Seismic response, Prediction techniques

Subsystem response uncertainty was characterized by use of a dimensionless K factor (the ratio of actual seismic response to predicted seismic response). This K factor was treated as a random variable in order to define quantitative

degrees of conservatism, nonconservatism, separation of random and modeling uncertainty, and nonlinear effects. Significant observations are reported.

**81-1707**

**Intrinsic Description of Three-Dimensional Shock Waves in Nonlinear Elastic Fluids**

T.C.T. Ting
Univ. Illinois at Chicago Circle, Chicago, IL 60680,
Intl. J. Engr. Sci., 19 (5), pp 629-638 (1981) 9 refs

Key Words: Shock wave propagation

The transport equations for the amplitude of 3-dimensional shock waves in nonlinear elastic fluids are examined. It is shown that, with the exception of the term which contains the mean curvature of the shock surface, the transport equations are almost identical to the transport equations for 1-dimensional nonlinear elastic solids. The stress, strain and velocity in thn latter are replaced by the pressure, specific volume and normal velocity, respectively. Therefore, the results obtained for 1-dimensional shock waves regarding whether the amplitudes of jump in stress, strain and velocity grow or decay simultaneously can be applied here to the jump in pressure, specific volume and normal velocity. New compatibility equations are obtained for the velocity gradients behind the shock wave.

**81-1708**

**Parameters Affecting the Relaxation Zone Behind Normal Shock Waves in a Dusty Gas**

O. Igra and G. Ben-Dor
Dept. of Mech. Engrg., Ben Gurion Univ. of the Negev, Beer Sheva, Israel,
Israel J. Tech., 18 (3-4), pp 159-168 (1980) 4 figs, 2 tables, 22 refs

Key Words: Shock wave propagation

A numerical solution for the problem of shock wave propagation into a dusty gas is presented for a steady one-dimensional case. The solution focuses on the extent of the relaxation zone length and identifies the parameters affecting it. It is shown that for high shock Mach numbers, radiative heat transfer plays an important role and should therefore be included in the energy balance equations of the flow. A few different correlations for the particle drag coefficient and its Nusselt number are presented and their influence on the extent of the relaxation zone length is discussed.

## VIBRATION EXCITATION

(Also see Nos. 1608, 1781, 1787, 1788, 1796)

**81-1709**

**Analysis of Unsteady Pressure Measurements on an Aerofoil Section with an Harmonically Oscillating, Slotted Flap**

K. Kienappel and D.F. Round
Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt e.V., Goettingen, Fed. Rep. Germany,
Rept. No. DVFLR-FB-80-22, 66 pp (Apr 1981)
N81-13929

Key Words: Airfoils, Aerodynamic characteristics, Control equipment, Harmonic response

An analysis is made of unsteady pressure distribution and aerodynamic coefficients measured for an airfoil and harmonically oscillating slotted control surface in a low speed wind tunnel. The influences on the pressure distribution and aerodynamic coefficients are examined: frequency of oscillation; flap steady deflection; section incidence; flow velocity and slot geometry, i.e. whether the slot is open or closed. There is a carry over between steady and unsteady pressure distributions, which although small at low incidence and flap deflections, becomes more important at higher values, particularly when separation related effects begin to affect the overall flow behavior.

**81-1710**

**Chaotically Transitional Phenomena in the Forced Negative-Resistance Oscillator**

Y. Ueda and N. Akamatsu
Nagoya Univ., Inst. Plasma Physics, Japan,
Rept. No. IJJP-482, 38 pp (Oct 1980)
N81-14842

Key Words: Self-excited vibrations, Periodic excitation, Synchronous vibration, Nonsynchronous vibration

When a periodic excitation is injected into the self-oscillatory system, either synchronized periodic oscillation or asynchronized nonperiodic oscillation comes out. Among the latter type of oscillations, chaotic oscillation frequently takes place which is different from almost periodic oscillations. Experimental studies using analog and digital computers were out to clarify the difference between the almost periodic oscillations and the chaotically transitional processes. Various strange attractors representing chaotically transitional processes and their average power spectra are given, discussed, and compared with the results obtained in the forced oscillatory systems.

**81-1711**

**Hydrodynamic Pressure and Added Mass for Axisymmetric Bodies**

F. Nilrat

Earthquake Engrg. Res. Ctr., California Univ., Berkeley, CA, Rept. No. UCB/EERC-80/12, 174 pp (May 1980)

PB81-122343

Key Words: Axisymmetric bodies, Fluid-induced excitation, Finite element technique, Computer programs

An effective finite element method for determining the hydrodynamic pressure distribution on rigid axisymmetric bodies oscillating in a fluid is presented. The bodies considered are symmetric about a vertical axis; and they can be either totally or partially submerged.

**81-1712**

**A Response Spectrum Method for Random Vibrations**

A.D. Kiureghian

Earthquake Engrg. Res. Ctr., California Univ., Berkeley, CA, Rept. No. UCB/EERC-80/15, NSF/RA-800201, 49 pp (June 1980)

PB81-122301

Key Words: Random vibration, Response spectra, Earthquake respo .se

A response spectrum method for stationary random vibration analysis of linear structures is developed. The method is based on the assumption that the input excitation is a wide-band stationary Gaussian process and the response is also stationary. However, it can also be used as a good approximation for the response to a transient stationary Gaussian input with a duration several times longer than the fundamental period of the structure. Various response quantities, including the mean-squares of the response and its time derivative, the response mean frequency, and the cumulative distribution and the mean and variance of the peak response are obtained in terms of the ordinates of the mean response spectrum of the input excitation and the modal properties of the structure. The formulation includes the cross-correlation between modal responses, which are shown to be significant for modes with closely spaced natural frequencies. The proposed procedure is demonstrated for an example structure that is subjected to earthquake induced base excitations.

**81-1713**

**A Method of Calculating the Vibratory Response of a Rigid Body to Arbitrary Excitation. Part 1. Maximum of 4 Supports Exerting Longitudinal Constraint Only, Arbitrary Location and Direction**

D.W. Parkins

Dept. for the Design of Machine Systems, Cranfield Inst. Tech., UK, Rept. No. DDMS/INTERNAL NOTE-1, 32 pp (July 1980)

PB81-126658

Key Words: Constrained structures, Multidegree of freedom systems, Vibration response, Computer-aided techniques

This report describes a method of calculating the vibratory response of a rigid body having six degrees of freedom. Any oscillatory excitation force or moment can be represented by choosing an appropriate combination of the specified forces and moments and their relative phase. A maximum of four support mountings may be modeled. Each support may independently be attached at any location, have its principal direction, and have any property up to that of a full Maxwell model. Calculation output comprises rectilinear and angular displacements with their relative phase, and 36 receptance terms, at any given frequency. The method is suited to solution by digital computer.

**81-1714**

**A Method of Calculating the Vibratory Response of a Rigid Body to Arbitrary Excitation. Part 2. Any Number of Supports Exerting Longitudinal and Lateral Constraint, Arbitrary Location and Direction**

D.W. Parkins

Dept. for the Design of Machine Systems, Cranfield Inst. Tech., UK, Rept. No. DDMS/INTERNAL NOTE-2, 32 pp (July 1980)

PB81-126682

Key Words: Constrained structures, Multidegree of freedom systems, Vibration response, Computer-aided techniques

This report describes a method of calculating the oscillatory response of a rigid body with six degrees of freedom excited by vibratory force or moment. There may be any number of supports. Each support may be attached at any point on the body and its principal axis may take any direction. Constraining forces may be exerted in both parallel and perpendicular directions to the support principal axis. Computation output comprises thirty-six receptance terms and relative phase at any given frequency. The method is expressed in general terms, and is convenient for solution by digital computer.

# MECHANICAL PROPERTIES

## DAMPING

(Also see Nos. 1658, 1725, 1737)

**81-1715**

**Fluid Damping for Circular Cylindrical Structures**

S.-S. Chen
Components Tech. Div., Argonne Natl. Lab., Argonne, IL 60439, Nucl. Engrg. Des., 63 (1), pp 81-100 (Jan 1981) 21 figs, 1 table, 26 refs

Key Words: Cylinders, Cylindrical shells, Viscous damping, Submerged structures, Nuclear reactor components

Fluid damping plays an important role for structures submerged in fluid, subjected to flow, or conveying fluid. This paper presents a summary of fluid damping for circular cylinders vibrating in stationary fluid, cross flow, and parallel flow.

**81-1716**

**Method of and Apparatus for Damping Nutation Motion with Minimum Spin Axis Attitude Disturbance**

H. Hoffman
NASA Goddard Space Flight Ctr., Greenbelt, MD, PAT-APPL-6-182 881, 21 pp (Aug 29, 1980)

Key Words: Spacecraft, Nutation damper

A method for damping nutation of a spinning spacecraft is described. The spin axis attitude disturbances were substantially reduced by controlling at least one nutation damping gas thruster to fire with nonuniform gas pulses. During the beginning of a nutation control sequence, the duration of successive gas pulses was gradually increased from zero to a predetermined maximum duration. The duration of successive pulses was then maintained constant for a time period. At the end of the nutation control sequence, the duration of successive gas pulses was gradually reduced to zero.

## FATIGUE

(Also see Nos. 1600, 1603, 1625, 1787, 1788, 1795)

**81-1717**

**Study of the Effect of Understress on Fatigue Life of Smooth Specimen of Carbon Steel under Rotating Bending and Reversed Torsion (On Behaviour of Crack Propagation)**

K. Tokaji, Z. Ando, and T. Yamada
Faculty of Engrg., Gifu Univ. 3-1, Nakamonzencho, Kagamigahara, Gifu, Bull. JSME, 24 (188), pp 273-281 (Feb 1981) 10 figs, 4 tables, 22 refs

Key Words: Fatigue life, Steel, Crack propagation

Two stress step multiple tests including understress are carried out using smooth specimens of two kinds of carbon steel, S10C and S45C, under rotating bending and reversed torsion. The effects of understressing on crack initiation and fracture are examined and discussed. Cumulative cycle ratio for crack initiation and fracture calculated by Miner's rule decreases with decreasing number of cycles in one block. Understressing influences the crack propagation behavior more strongly than the crack initiation and results in an increase in the crack propagation rate under overstress for smaller number of cycles. Acceleration and deceleration phenomena are recognized in crack propagation behavior during overstressing just after the stress changes.

**81-1718**

**Fatigue Life Calculation for Increasing or Decreasing Vibration Load Based on Two-Stage Tests (Lebensdauerberechnung für mehrstufig steigende oder fallende Schwingbelastung auf der Grundlage von Zweistufenversuchen)**

G. Schott
Technische Universitat Dresden, Sektion Grundlagen des Maschinenwesens, German Dem. Rep., Maschinenbautechnik, 29 (12), pp 566-569 (Dec 1980) 8 figs, 2 refs
(In German)

Key Words: Fatigue life

The represented calcualtion method results from the behavior of fatigue of materials in two-stage tests. The fatigue state caused by a preliminary load influences the behavior of fatigue during the following vibration load. The residual life values still existing after preliminary load at the individual stress values can be read off sequential Wohler curves.

**81-1719**
**Fatigue Integrity Assessment**
T.V. Duggan
Dept. Mech. Engrg. and Naval Architecture, Portsmouth Polytechnic, Anglesea Bldg., Anglesea Rd., Portsmouth PO1 3DJ, UK, Intl. J. Fatigue, 3 (2), pp 61-70 (Apr 1981) 7 figs, 1 table, 28 refs

Key Words: Fatigue life, Crack detection, Crack propagation

A detailed discussion of studies made on the fatigue process – with an emphasis on those appropriate to the design of components – is presented. It complements works concerned with fatigue integrity which have been published previously.

**81-1720**
**Fatigue Behaviour under Out-of-Phase Bending and Torsion**
D.L. McDiarmid
The City Univ., London, UK, Aeronaut. J., 85 (842), pp 118-122 (Mar 1981) 6 figs, 1 table, 14 refs

Key Words: Fatigue life, Flexural vibration, Torsional vibration, Phase effects, Blades, Propeller blades, Shafts, Propellers

The ability to design components such as drive shafts, propellers and rotor blades to carry combined bending and torsion alternating stresses, which may be out-of-phase is a common requirement in industry. This paper extends the application of the theory to investigate fatigue under out-of-phase bending and torsion with regard to the stress conditions on the planes of maximum shear stress.

## ELASTICITY AND PLASTICITY

**81-1721**
**Fracture Mechanics and Testing of Steel for Large Rotors**
A. Freddi
Engrg. Faculty, Univ. Bologne, Italy, Intl. J. Fatigue, 3 (2), pp 71-76 (Apr 1981) 12 figs, 2 tables, 18 refs

Key Words: Rotors, Turbine components, Steel, Fracture properties

A method is presented for integrity assessment of turbine rotors, based on theoretical and experimental evaluations. Based on the results of tests done on plastic models, an 'equivalent' elliptical defect is introduced to represent two interacting coplanar defects. A fracture mechanics method is used to characterize a Ni-Cr-Mo-V steel turbine disc.

# EXPERIMENTATION

## MEASUREMENT AND ANALYSIS

(Also see Nos. 1690, 1746, 1781)

**81-1722**
**An Analysis of Vibration Sensitivity in Hydrophone Design**
G.D. Hugus, III
Naval Res. Lab., Washington, D.C., Rept. No. NRL-MR-4295, 19 pp (Nov 1980)
AD-A092 809

Key Words: Hydrophones, Vibration response, Fluid-induced excitation

Hydrophones used in the ocean produce spurious outputs because of vibration sensitivity that can severely degrade measurement accuracy. Sources of these vibration inputs are ocean surface wave, flow turbulence, and induced non-acoustic mechanical vibration. The hydrophone response to these vibrations is a noise voltage output. This can lead to a signal-to-noise problem, particularly when measurements of small sound pressure levels are to be made. This report presents an analysis of the vibration responses of three typical piezoelectric hydrophone sensor elements configurations and gives design methods and constraints for reducing the problem of vibration sensitivity to an acceptable level. The sensor element configurations analyzed are the radially polarized cylindrical shell. The analysis is carried out for two effects. First an electromechanical analysis is given of the voltage sensitivity of each of the three sensor configurations to the inertial effect of acceleration inputs. The second effect analyzed is the voltage sensitivity of a pressure sensitive sensor element to the hydrostatic pressure amplitude caused by periodic vertical displacements of a hydrophone.

**81-1723**
**Electronic Compensation of a Force Transducer for Measuring Fluid Forces Acting on an Accelerating Cylinder**
K.G. McConnell and Y.-S. Park

Engrg. Science and Mechanics and Engrg. Res. Inst., Iowa State Univ., Ames, IA 50011, Exptl. Mechanics, 21 (4), pp 169-172 (Apr 1981) 5 figs, 6 refs

Key Words: Transducers, Interaction: solid-fluid

The paper describes a low-cost and effective means of amplifying and filtering low-level signals as well as removing acceleration sensitivity of the transducer.

**81-1724**

**The Measurement of Transient Changes in Rotor Angle of a Microsynchronous Alternator**

D.W. Auckland and R. Shuttleworth

Univ. of Manchester, Manchester M13 9PL, UK, J. Phys. E. (Sci. Instr.), 14 (2), pp 151-152 (Feb 1981) 2 figs, 1 ref

Key Words: Measuring instruments, Transient response, Rotors

In this laboratory, as in many others, the performance of large turbo alternators is studied using microsynchronous alternators which are scaled models of practical machines. An important aspect of a machine's behavior is the manner in which its rotor angle changes following a severe transient disturbance near its terminals. An instrument for accurate measurement of transient changes in the rotor angle of a micro-alternator without the machine having to be synchronized is reported.

**81-1725**

**An Apparatus for Determination of the Effect of Mean Strain on Damping**

R.J. Hooker and D.J. Mead

Inst. Sound Vib. Res., Univ. Southampton, Southampton, UK, J. Phys. E. (Sci. Instr.), 14 (2), pp 202-207 (Feb 1981) 10 figs, 1 table, 6 refs

Key Words: Measuring instruments, Damping coefficients

A description is given of an apparatus which enables the measurement of damping during vibration with non-zero mean strain. The loading condition is torsion on a pair of cylindrical specimens, which may be solid or hollow. Mean strain is applied by opposite pre-twist in the two specimens. Damping is determined from energy input during steady resonant vibration, although both frequency response and free decay techniques can also be used. An account is given of the apparatus development and operation, with particular reference to the use of a test specimen/low damping specimen combination which effectively halves the required power input and which allows a correction for extraneous losses to be applied.

**81-1726**

**Investigation of Dynamic Behaviour of Non-Contacting Measuring Devices by a Transient Displacement Method**

J.S. Field

Natl. Measurement Lab., CSIRO, Chippendale, Australia, Microtecnic, 3, pp 28-30 (1980) 6 figs

Key Words: Measuring instruments, Proximity probes, Calibrating, Transducers

To investigate the dynamic response characteristics of a non-contacting displacement measuring system it is necessary to produce small, precisely known displacements between reference surface and the measuring probe of the instrument. These displacements are often obtained by driving an electromechanical transducer with a sinusoidally varying signal. A method is given for characterization of probes.

**81-1727**

**Research and Development Program for Flight Loads Assessment of Engine/Airframe Integration. Phase 1**

R. Fost, J. Dollman, and R. Jutras

Aircraft Engine Group, General Electric Co., Cincinnati, OH, Rept. No. AFAPL-TR-79-2071, R79-AEG315, 105 pp (Sept 1979)

AD-A093 157

Key Words: Blades, Aircraft engines, Vibration measurement, Measuring instrumentation, Flight tests

Obtaining a better understanding of critical turbine engine component behavior under actual flight conditions is essential to the development of improved component design life criteria and proper engine/airframe structural integration. Current airfoil vibratory response measurement techniques preclude obtaining airfoil vibratory data during engine development flight test. To obtain this needed data, this program was directed at developing a prototype flight engine blade vibration measurement system.

**81-1728**
**Swept Narrow Band Random on Random**
F.T. Mercer
Vib. and Model Testing Div., Sandia Labs.; Albuquerque, NM, Rept. No. SAND-80-1534, 34 pp (Aug 1980)
N81-11433

Key Words: Spectrum analyzers, Fourier analysis, Vibration analyzers, Vibration control, Random response

The implementation of swept narrow band random on random on the HP5451C Fourier Analyzer System and the HP5427A Vibration Control System is discussed. Up to five narrow bands of a dynamically changing narrow band random spectrum were super-imposed on a broad band random spectrum and swept at various rates to simulate field environments.

**81-1729**
**A Survey to Assess the Reliability of Mobility Measurement Techniques**
D.J. Ewins
Imperial College Science and Tech., London, UK, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA. Apr 7-9, 1981, pp 115-125, 6 figs, 2 tables, 3 refs

Key Words: Vibration measurement, Measurement techniques, Mobility method

In recent years there has been a marked increase in the use of mobility measurement techniques in the course of studies of structural vibration. In many applications, measured mobility data are subsequently used for modal analysis and in these cases the accuracy of the data is crucial to the success of the process. A survey has recently been conducted in Europe to assess the consistency of mobility measurements made on a set of test structures which were circulated amongst some thirty laboratories, all of whom use mobility measurements regularly in the course of their engineering studies. A selection of results from this survey is presented and discussed, together with examples of their application to modal analysis and other numerical processes. Some conclusions are drawn regarding the suitability of different testing techniques and of the time requirements for making mobility measurements.

**81-1730**
**A Modern Measuring Technique - Examples of Application for Holographic Interferometry (Part 3)**
**(Ein modernes Messverfahren im Einsatz - Anwendungsbeispiele zur holografischen Interferometrie (Teil 3)**
G. Frankowsi, L.L. Mente, and G. Wernicke
Akademie der Wissenschaften der DDR, Zentralinstitut f. Mathematik und Mechanik, German Dem. Rep., Maschinenbautechnik, 29 (12), pp 552-556 (Dec 1980) 8 figs, 1 table, 3 refs
(In German)

Key Words: Measurement techniques, Holographic techniques

The variety of applications of various holographic interferometry techniques is illustrated by means of three examples. The double illumination technique is used to investigate the deflection of various shapes of small plate springs statically loaded in the center. Real time technique was used to determine various material properties. The effect of crystallite in a plate on its deflection was investigated by the mean time technique by comparing the vibration mode shapes of homogenous and inhomogenous plates.

**81-1731**
**Padé Approximants of Noncausal Digital Filters**
C. Chen
Dept. Electrical Engrg., State Univ. New York, Stony Brook, NY 11794, J. Franklin Inst., 310 (4/5), pp 209-213 (1980) 7 refs

Key Words: Filters, Digital filters, Time domain method, Frequency domain method

Based on the requirement of stability and causality, this paper presents a new method of designing IIR digital filters. The method is essentially a combination of a time-domain and a frequency-domain technique. Because of this new derivation, the method can be readily extended to two or more dimensional noncausal digital filters.

**81-1732**
**Integrating-Average Sound-Level Meters**
W.R. Kundert
Industrial Resources, Harvard, MA, S/V, Sound Vib., 15 (3), pp 18-20 (Mar 1981) 5 figs

Key Words: Sound level meters, Noise measurement, Measuring instruments

The integrating sound-level meter is introduced and contrasted with the "ordinary" sound-level meter and the industrial dosimeter. Applications and features of integrating sound-level meters are presented. The importance of dynamic range and the ability to handle short duration impulsive sounds are discussed.

**81-1733**
**Shock Test Pulse Display and Analysis**
G.R. Henderson
GHI Systems, Inc., Ranchos Palos Verdes, CA, Test, 43 (2), pp 8-9, 11 (Apr/May 1981) 3 figs

Key Words: Shock tests, Testing instrumentation, Time domain method

This discussion deals with the time domain, or acceleration, velocity, and displacement information that can be obtained with a relatively inexpensive system for recording, display, and analysis of shock test data.

**81-1734**
**A Digital Electronic Method for the Measurement of Blast Wave Parameters**
V.S. Sethi, S. Srinivasan, V. Bodhankar, O.P. Khurana, R. Paul, and G. Chand
Terminal Ballistics Res. Lab., Sector-30, Chandigarh-160020, India, J. Phys. E. (Sci. Instr.), 14, pp 457-460 (Apr 1981) 5 figs, 6 refs

Key Words: Shock waves, Measurement techniques, Electronic instrumentation, Digital techniques

The important blast wave parameters such as peak overpressure, positive duration and impulse are normally measured from oscillographic records of pressure-time curves. An electronic circuit which measures these parameters simultaneously and displays them in digital form, is described here.

**81-1735**
**The Optical Grating Hydrophone**
B.W. Tietjen
Electronic Systems Div., General Electric Co., Syracuse, NY 13221, J. Acoust. Soc. Amer., 69 (4), pp 993-997 (Apr 1981) 7 figs, 10 refs

Key Words: Sound detectors, Hydrophones, Underwater sound

The optical grating hydrophone has been shown to be an effective underwater acoustic detector. It offers all of the advantages of a direct-intensity modulating device, and can be built quite simply and inexpensively. Choices of grating densities, bias, optical power, and hydrophone configuration affords much design flexibility regarding sensitivity, dynamic range, size, and operating frequency range. Several working models have been constructed and verify analytical predictions. The optical grating concept is very promising as a near-term, practical operating optical hydrophone for sonar applications.

## DYNAMIC TESTS
(Also see Nos. 1605, 1796, 1797, 1798)

**81-1736**
**The Use of Sound Emission Analysis in Compression and Bursting Tests (Erfahrungen bei der Anwendung der Schallemissionsanalyse in Druck- und Berstversuchen)**
W. Morgner, H. Heyse, and K. Theis
Technische Hochschule, Otto von Guericke, Magdeburg, German Dem. Rep., Maschinenbautechnik, 30 (2), pp 84-87 (Feb 1981) 10 figs, 12 refs
(In German)

Key Words: Acoustic emission, Nondestructive testing

The application of sound emission technique in the testing of metal containers is described. This nondestructive technique enables an early detection of leaks, plastic deformations, or cracks in the structure.

## SCALING AND MODELING
(Also see No. 1604)

**81-1737**
**A Fluid Damping Distortion in FIV Scale Modeling**
T.M. Mulcahy
Components Tech. Div., Argonne Natl. Lab., Argonne, IL 60439, Nucl. Engrg. Des., 63 (1), pp 101-107 (Jan 1981) 3 figs, 13 refs

Key Words: Scaling, Fluid-induced excitation, Viscous damping, Structural members, Nuclear reactor components

The prediction of flow-induced vibrations (FIV) of structural components often must rely upon scale model test results, because direct forced response predictions are beyond the state-of-the-art. Since viscosity effects often are distorted in reduced scale model tests, the identification of fluid forces which are Reynolds number dependent is essential to the acquisition of meaningful test results. Toward this end, the fluid damping forces exerted on a vibrating tube by a surrounding narrow, fluid filled, finite length annular region are shown to be relatively larger in the model than in the prototype. A theory is proposed for estimating the magnitude of this unconservative distortion in model testing.

## DIAGNOSTICS

**81-1738**

**Solving Pump Problems . . . Using Vibration Spectrum Analysis**

S. Goldman

Nicolet Scientific Corp., Northvale, NJ, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 27-33, 6 figs

Key Words: Pumps, Diagnostic techniques, Spectrum analysis, Vibration control

The basics of pump operation, vibration spectrum analysis, and problem-solving techniques are summarized. The author discusses the advantages of spectrum analysis in diagnosing pump vibration, reviews forcing and natural frequencies, and explains what to look for on the spectrum analyzer.

**81-1739**

**Ingestion of a Suction Screen into a Circulator Compressor**

C. Jackson

Monsanto Co., Texas City, TX, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 39-55, 26 figs

Key Words: Compressors, Unbalanced mass response, Diagnostic techniques

This paper covers the effects from unbalance of a 24 x 24 pipeline booster type compressor impeller due to ingestion, in service, of a suction screen. Minimal data is shown of the compressor's unbalanced condition. Photos are included to show the results of the ingestion. More data is shown on runup and operation of the compressor and the drive turbine. The data presented after repairs, however, allows a convenient base to discuss several points in analysis.

**81-1740**

**Analytical and Field Study of a Turbogenerator Vibration Problem**

F. Aguilar

Instituto Mexicano del Petroleo, Mexico City, Mexico, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 21-25, 12 figs

Key Words: Turbomachinery, Turbogenerators, Generators, Foundations, Rotors, Fluid-film bearings

The dynamic behavior observed during the commissioning of two power generation sets of 32,000 KW are analyzed. Some results of the field vibration measurements and the spectral and orbital analysis carried out to explain the observed behavior of the units are presented. Also the analytical rotor dynamics performed to correlate the vibration measurement with the expected results are discussed including the frequency analysis of the unit foundation that was made using the finite element method.

## BALANCING

**81-1741**

**Multi-Plane High Speed Balancing Techniques and the Use of a High Specific Stiffness Ti-Borsic Material for Vibration Control**

G. Hamburg and W. Pentek

Teledyne CAE, Toledo, Ohio, Rept. No. TCAE-1701, AFWAL-TR-80-2056, 115 pp (Feb 1980)

AD-A093 122

Key Words: Balancing techniques, Multiplane balancing technique, Shafts (machine elements), Composite materials, Flexible rotors

This report documents results of multi-plane high-speed balancing demonstration of a flexible rotor and a preliminary design analysis for a high specific stiffness composite material shaft. Both studies had as their objective the management of small turbofan engine low pressure shaft bending critical

speeds. The prototype flexible rotor was successfully balanced through 3 critical speeds reaching a maximum of 28,000 rpm, which was 74% of the maximum intended rotor speed of 38,000 rpm. Balancing for operation above the 4th critical speed, which was predicted to occur at 33,000 rpm, was prevented due to a sub-synchronous rotor instability. Causes of the instability were attributed to the configuration of the squeeze film bearing damper and the engine rotor support structure as opposed to any limitation of the balancing techniques employed. The preliminary composite shaft design was completed assuming that a Ti-Borsic metal matrix composite with 60% fiber volume and 40% metal matrix would be used. This 'stiff' shaft was designed as a direct substitute for the multi-plane high speed balancing demonstrator rotor. Analytical studies indicate that the composite rotor will have a 24% third critical speed margin when operating at 38,000 rpm.

**81-1742**

**Balancing Pitfalls - High Speed Turbine Rotors**

G.S. Schmidt
Installation and Service Engrg. Div., General Electric Co., Schenectady, NY, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 35-38, 3 tables, 1 ref

Key Words: Balancing techniques, Steam turbines, Turbines, Computer-aided techniques

This paper concerns the author's experience in applying balance technology to balancing steam turbines in the field. Current technology and research in the area of rotor dynamics have resulted in the production of excellent instrument sensors and analyzers and precise operational controls. Based on these developments, it might be assumed that field balancing a turbine is a straightforward procedure. The author's experience, however, showed that this is not always the case as each balancing application is unique, and there is always the chance that minor deviations from normal operating conditions may create problems during balancing. Such problems could result in costly delays.

**81-1743**

**On the Balancing of Flexible Rotors Independent on Boundary Conditions**

I. Ballo
Inst. of Machine Mechanics, Slovak Academy of Sciences, Dubravska cesta 26, 80931 Bratislava, Czechoslovakia, Ing.-Arch., 50 (3), pp 177-185 (1981) 3 figs, 12 refs

Key Words: Balancing techniques, Rotors, Flexible rotors

Recent methods for balancing flexible rotors are based on the approximation of the deflection brought about by its unbalance influenced by the normal modes of the rotor. Since normal modes depend on boundary conditions, the so performed balancing of the rotor also depends on them. This fact may lead to some difficulties if the stiffness of the rotor bearings is considerably nonisotropic in various radial directions or if the rotor has been balanced on the balancing machine with stiffness characteristics of bearing mounting essentially other under actual operation. A method is suggested in the paper that removes the mentioned dependence of flexible rotor balancing on its boundary conditions. It is based on the approximation of the deflection by a complete system of coordinate functions independent on the stiffness of supporting its ends. Hence the flexible rotor, one balanced according to this method, will continue to be balanced even under an arbitrary stiffness of its bearings.

## MONITORING

**81-1744**

**Compressor Blade Monitoring System for a VA1310 (Allis Chalmers) Wind Tunnel Compressor**

D. Wilson and J. Frarey
Shaker Research Corp., Ballston Lake, NY, Rept. No. AFWAL-TR-80-3072, 58 pp (July 1980)
AD-A092 920

Key Words: Monitoring techniques, Compressor blades, Blades

The purpose of the work summarized in this report is to identify and develop a cost effective, reliable procedure for identifying potential blade failures in time to prevent the actual occurrence. The procedure is developed for application to an Allis-Chalmers ten-stage, axial flow compressor, Model VA 1310. The approach followed in conducting this study included a review of the current techniques used to insure blade integrity, a review of other approaches as described in literature for verifying the condition of compressor blades and, finally, development of a technique suitable for use with the VA 1310 compressor.

**81-1745**

**Turbine Engine Fault Detection and Isolation Program. Phase 1. Requirements Definition for an**

**Integrated Engine Monitoring System. Volumes 1 and 2**
L. Baker, R. DeHoff, and W. Hall, Jr.
Systems Control, Inc. (VT), Palo Alto, CA, Rept. No. AFWAL-TR-80-2053, 123 pp (Apr 1980)
Vol. 1: AD-A093 225
Vol. 2: AD-A093 226

Key Words: Monitoring techniques, Turbine engines, Aircraft engines

This report presents the results of an intensive study of the Air Force maintenance/logistics process based on a selected sample of tactical bases, depots, and major commands. The objective is to define the requirements that the Air Force engine management structure imposes on automated data integration, in general, and engine performance monitoring, in particular. Such an automated integration of turbine engine monitoring system data with current data systems requires coordination between a variety of sources, both manual and automated. The results of this study are the requirements for such integration based on typical Air Force maintenance needs.

## 81-1746
**Accelerometer Applications in a Process Plant**
K.Z. Witwer
Dow Chemical U.S.A., Freeport, TX, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 133-135

Key Words: Monitoring techniques, Accelerometers

The advantages of using accelerometers for condition monitoring of critical rotating machinery are indicated. Pumps, compressors, gearboxes, cooling towers, steam and gas turbines, blowers, conveyors, centrifuges, and fans are involved.

## 81-1747
**Trends, Patterns and Parameters**
R.M. Stewart
Stewart Hughes Ltd., UK, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 137-153, 6 figs, 8 refs

Key Words: Monitoring techniques

This paper illustrates how technical knowledge and information may be fed into a monitoring program to raise its effectiveness if and when the need exists.

## 81-1748
**Time Marches On – Changing Concepts in Machinery Condition Monitoring**
J.S. Mitchell and J.L. Frarey
Turbomachinery Consultant, San Juan Capistrano, CA, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 127-132, 1 fig

Key Words: Monitoring techniques, Instrumentation

There is a danger in any area of technology that is rapidly improving to not take full advantage of the improvements. Typically, this happens when we implement the same concepts with better building blocks. The authors feel that periodically the way we do things should be examined to see if we are taking full advantage of the tools available. This paper develops a machinery surveillance system based on the electronic technology available rather than on how we have been doing it.

## 81-1749
**Computerized Condition Monitoring System – User's Viewpoint**
A. Chou
Engrg. Dept., Mobil Res. and Dev. Corp., Princeton, NJ, Proc., Machinery Vibration Monitoring and Analysis Seminar and Meeting, New Orleans, LA, Apr 7-9, 1981, pp 95-105, 8 figs, 7 refs

Key Words: Monitoring techniques, Computer-aided techniques, Rotating structures

A computerized condition monitoring (CCM) system is one of the tools for "on-condition" maintenance (OCM) of rotating equipment. Because a CCM system is computer based, it has large capability for data management to present useful information on the condition of the monitored machinery from the voluminous data collected. Its usefulness is only limited by our knowledge of the machinery conditions and our ability in analyzing the data. Though, the application of the CCM systems is growing, its potential has not yet been fully exploited. This paper discusses the design philosophy of a CCM system.

## 81-1750
**Acoustic-Emission Crack Monitoring in Fracture-Toughness Tests for AISI 4340 and SA533B Steels**
H. Takahashi, M.A. Khan, M. Kikuchi, and M. Suzuki

Tohoku Univ., Sendai, 980/Japan, Exptl. Mechanics, 21 (3), pp 89-99 (Mar 1981) 19 figs, 5 tables, 21 refs

Key Words: Monitoring techniques, Steel, Acoustic emission, Fracture properties

The feasibility of using acoustic-emission techniques for the characterization of fracture resistance in AISI 4340 and SA533B steels is examined. The critical value of J-integral is measured with a single small specimen (compact tension) loaded in the elastic-plastic range at room temperature. Initiation is detected during loading by acoustic emission. A new AE procedure for crack-growth monitoring in fracture-toughness specimens has been proposed. The possibility of discriminating AE signals from noncritical sources, such as void nucleation during crack-tip plastic deformation and signals from a growing crack, is discussed.

**81-1751**

**In-Flight Fatigue Crack Monitoring Using Acoustic Emission**

P.H. Hutton and J.R. Skorpik

Battelle, Pacific Northwest Labs., P.O. Box 999, Richland, WA 99352, ISA Trans., 20 (1), pp 79-83 (1981) 11 figs

Key Words: Acoustic emission, Monitoring techniques, Crack detection, Aircraft

The purpose of the work described is to evaluate the use of acoustic emission (AE) methods to detect fatigue crack growth in aircraft structure during operation. A unique AE monitor system installed on an Australian Air Force Macchi 326 aircraft has detected AE which correlates with slow crack growth during operation over the past year and a half.

# ANALYSIS AND DESIGN

## ANALOGS AND ANALOG COMPUTATION

**81-1752**

**An Analytical Technique for Approximating Unsteady Aerodynamics in the Time Domain**

H.J. Dunn

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TP-1738, L-13255, 31 pp (Nov 1980) N81-11422

Key Words: Approximation methods, Aerodynamic loads, Time domain method, Aircraft wings

An analytical technique is presented for approximating unsteady aerodynamic forces in the time domain. The order of elements of a matrix Pade approximation was postulated, and the resulting polynomial coefficients were determined through a combination of least squares estimates for the numerator coefficients and a constrained gradient search for the denominator coefficients which insures stable approximating functions. The number of differential equations required to represent the aerodynamic forces to a given accuracy tends to be smaller than that employed in certain existing techniques where the denominator coefficients are chosen a priori. Results are shown for an aeroelastic, cantilevered, semispan wing which indicate a good fit to the aerodynamic forces for oscillatory motion can be achieved with a matrix Pade approximation having fourth order numerator and second order denominator polynomials.

## ANALYTICAL METHODS

(Also see No. 1577)

**81-1753**

**Alternative Derivation of Equations of Motion**

J. Korn

Middlesex Polytechnic, Bounds Green Road, London N11 2NQ, UK, J. Franklin Inst., 311 (3), pp 131-150 (Mar 1981) 11 figs, 17 refs

Key Words: Equations of motion

Equations of motion in the form of sets of non-linear differential equations are derived for dynamic systems which may exhibit simultaneous changes in their electrical, fluid, mechanical and thermal states. These equations are based on considerations of the physics of components and their eventual topology when forming an assembly. The effect of thermal environment is shown when its capacity is finite and when it is not.

**81-1754**

**Analytic Methods in Structural Dynamics**

H.P. Geering

Swiss Fed. Inst. Tech., Zurich, Switzerland, Israel J. Tech., 18 (1-2), pp 84-90 (1980) 6 refs

Key Words: Dynamic structural analysis, Eigenvalue problems

The purpose of this paper is to show the following: In the dynamic analysis of large (non-substructured) structures, the only step to be numerically executed is solving the eigenproblem. The transient response and steady state response to periodic loads, the transient response to aperiodic loads of finite duration, and the response spectra to stationary random loads can be calculated analytically, i.e., without numerical integration. A significant data reduction is possible by dropping all of the irrelevant components of the eigenvectors without loss of relevant information. For this purpose, the notion of dynamic elasticity transfer matrix is introduced. For substructured systems, the eigenproblems can be solved for each substructure seperately with the interface boundary degrees of freedom free (unclamped). For the complete system, the transient response to periodic loads and the response spectra to stationary random loads can thus be calculated exactly and analytically. If desired, modal approximations can be made on the substructure level.

**81-1755**

**Complementary Formulations in Vibrations: Bond Graph Structures and Modal Transformations**

D. Karnopp

Dept. of Mech. Engrg., Univ. of California, Davis, CA 95616, J. Franklin Inst., 310 (6), pp 303-316 (1980) 5 figs, 1 table, 8 refs

Key Words: Modal analysis, Bond graph technique, Lumped parameter method, Vibrating structures

Lumped parameter, undamped vibratory system models are studied starting from a vector bond graph representation which yields a symmetric set of equations of motion in terms of momenta and displacements. Four additional formulations are obtained depending upon the choices of displacement or impulse-momentum degrees of freedom including the classical formulation in terms of mass displacements. Differences in terms of forcing and response variables are found among the alternative formulations and differences in system order are explained. A new form of normal mode equations is developed using first order symmetric variables and a bond graph representation is given. Advantages in the use of the new model analysis for subsystem coupling are discussed.

**81-1756**

**Modal Methods in the Dynamics of Systems with Non-Classical Damping**

R.W. Traill-Nash

School of Civil Engrg., Univ. of South Wales, Kensington, N.S.W., Australia, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (2), pp 153-169 (1981) 8 figs, 8 tables, 25 refs

Key Words: Modal analysis, Mode displacement method, Force summation method, Normal modes, Damped modes

Methods of modal analysis in structural dynamics are discussed and their derivations briefly given. These include the conventional mode displacement method and the force summation method, employing normal modes, and the analogous procedures with damped modes. In the latter, dynamic response equations are not coupled. Dynamic loading solutions by the four approaches, each taking account of the non-classical damping distribution, are demonstrated with a simple model representing a structure on a compliant foundation. The results strongly suggest that the use of damped modes with force summation could be the most effective procedure when damping is non-classical.

**81-1757**

**A General Dynamic Synthesis for Complex Structures Composed of Substructures**

A. Hale

Virginia Polytechnic Inst. and State Univ., Ph.D. Thesis, 166 pp (1980)
UM 8105331

Key Words: Substructuring methods, Structural synthesis, Continuous parameter method, Lumped parameter method

A general substructure synthesis method is developed for the dynamic analysis of complex flexible structures.

**81-1758**

**A Linearization Scheme for Hysteretic Systems Subjected to Random Excitation**

R.L. Grossmayer

Vienna Inst. Tech., Austria, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (2), pp 171-185 (Mar/Apr 1981) 8 figs, 28 refs

Key Words: Linear theories, Random excitation, Hysteretic damping, Damping coefficients, Stiffness coefficients

The problem of predicting the response of hysteretic yielding systems under random excitation is considered. The paper presents a linearization scheme which is motivated by exten-

sive simulation studies of the bilinear hysteretic system. Effective stiffness and damping parameters are presented. The accuracy of the various steps of the scheme is examined. The approach gives results which are in close agreement with simulation estimates even for large-system non-linearity.

### 81-1759

**Asymptotic Stability of Randomly Perturbed Linear Periodic Systems**

P.L. Chow and K.L. Chiou
Dept. of Math., Wayne State Univ., Detroit, MI 48202, SIAM J. Appl. Math., 40 (2), pp 315-326 (Apr 1981) 15 refs

Key Words: Random parameters, Periodic structures

For a class of linear periodic systems with randomly perturbed coefficients, an explicit criterion is obtained for the system to be asymptotically stable in the mean-square or an almost sure sense. The criterion relates the moduli of the characteristic multipliers for the reduced periodic system to the size and the correlation length of the random perturbation. The result is applied to a randomly perturbed, periodic Hamiltonian system and to the stability of periodic solutions for nonlinear systems with state-dependent noises.

### 81-1760

**A Method for Analysis of Non-Linear Vibrations Caused by Modulated Random Excitation**

P.-T.D. Spanos
Dept. Aerospace Engrg. and Engrg. Mechanics, Univ. Texas, Austin, TX 78712, Intl. J. Nonlin. Mechanics, 16 (1), pp 1-11 (1981) 2 figs, 22 refs

Key Words: Nonlinear systems, Damped systems, Random excitation

A method for analyzing the response of a class of weakly non-linear and lightly damped systems to a separable non-stationary random excitation is presented. The random excitation is represented as the product of a slowly varying modulating deterministic function and a broad-band stationary process. Using an averaging procedure a first order equation governing the time evolution of the response amplitude is derived. The Fokker-Planck equation which describes the diffusion of the probability density function of the response amplitude is considered. A particularly convenient basis of orthonormal functions, as well as, necessary formulae for the determination of an approximate solution of the Fokker-Planck equation by means of the Galerkin technique are presented. Furthermore, based on this solution an equation is given for the determination of the statistical moments of the response amplitude.

### 81-1761

**On Dynamic Stability and Quasi-Bifurcation**

L.H.N. Lee
Dept. Aerospace and Mech. Engrg., Notre Dame, IN 46556, Intl. J. Nonlin. Mecha., 16 (1), pp 79-87 (1981) 7 figs, 3 refs

Key Words: Dynamic stability, Multidegree of freedom systems, Bifurcation theory

In this paper, a dynamic stability concept and a quasi-bifurcation criterion introduced in a recent paper are clarified. A simple dynamic system of four degrees of freedom is employed to illustrate the concept and the significance of the criterion.

### 81-1762

**Bounds for Large Plastic Deformations of Dynamically Loaded Continua and Structures**

J. Ploch and T. Wierzbicki
Inst. Mathematics, Warsaw Tech. Univ., Warsaw, Poland, Intl. J. Solids Struc., 17 (2), pp 183-195 (1981) 10 figs, 13 refs

Key Words: Boundary value problems, Pulse excitation, Beams, Cylindrical shells

A theorem is developed which provides bounds for maximum displacements of impulsively loaded rigid-plastic continua and structures, valid in the range of large deformations. A Lagrangian description is used. In contrast to the case of infinitesimal deformations, the existence of the bound is shown to be closely related to the question of stability. A simple criterion of the applicability of the theory is derived along with an equality which bounds from above permanent displacement at a chosen point of the body. The solution of an actual dynamic problem is then reduced to the determination of a statically admissible system of stresses and displacements satisfying the equations of equilibrium in the deformed configuration and violating nowhere the yield condition. Application of the theorem is given by finding estimates on moderately large deflections of beams and cylindrical shells subjected to impulsive loading.

## 81-1763

**Nonlinear Oscillations of the Third Order Systems. Part III. Parametric Oscillation**

N. Van Dao
Polish Academy of Sciences, Inst. Fundamental Technological Res., Warszawa, Poland, J. Tech. Phys., 21 (2), pp 253-265 (1980) 5 figs, 12 refs

Key Words: Nonlinear vibrations, Parametric excitation, Coulomb friction, Turbulent friction

The parametric oscillation of the third-order system is investigated. The approximate solution of the motion equation is constructed and stationary solutions are studied. The stability condition of the stationary oscillation is reviewed. The Routh-Hurwitz criteria are taken out. The influence of the Coulomb friction on the parametric oscillation is considered. The influence of the turbulent friction on the parametric oscillation is studied.

## 81-1764

**On the Use of Complex Form of the Strouhal Number in the Study of Nonlinear Aeroelasticity**

Z. Kopřiva
Polish Academy of Sciences, Inst. Fundamental Technological Res., Warszawa, Poland, J. Tech. Phys., 21 (2), pp 245-252 (1980) 4 figs, 12 refs

Key Words: Strouhal number, Fluid-induced excitation, Aeroelasticity

This paper contains basic information on the mathematical tools used in a study on optimization of aeroelasticity for a system of interfering surfaces.

## 81-1765

**Crack Problems for a Rectangular Plate and an Infinite Strip**

M.B. Civelek and F. Erdogan
Lehigh Univ., Bethlehem, PA, Rept. No. NASA-CR-163721, 41 pp (July 1980)
N81-11419

Key Words: Crack propagation, Plates, Rectangular plates, Beams, Strips

The general plane problem for an infinite strip containing multiple cracks perpendicular to its boundaries is considered. The problem is reduced to a system of singular integral equations. Two specific problems of practical interest are then studied in detail. The first problem explores the interaction effect of multiple edge cracks in a plate or beam under tension or bending. The second problem is that of a rectangular plate containing an arbitrarily oriented crack in the plane of symmetry. Particular emphasis is placed on the problem of a plate containing an edge crack and subjected to concentrated forces.

## 81-1766

**An Accurate Method for Computing Shocks in Non-Linear Wave Propagation**

P.B. Bailey and P.J. Chen
Sandia Natl. Labs., Albuquerque, NM 87185, Wave Motion, 3 (2), pp 137-143 (Apr 1981) 3 figs, 5 refs

Key Words: Nonlinear response, Wave propagation, Shock wave propagation

The numerical computation of waves in non-linear materials often entails using finite difference schemes. The presence of shocks in the waves causes difficulties for the schemes which would otherwise be entirely satisfactory. These schemes can, however, be modified so as to yield highly resolved solutions even in the presence of shocks. Essentially, the method entails subtracting out the shock, solving the resulting problem, and then adding back the shock to obtain the solution to the original problem. The method is illustrated by non-trivial examples.

## 81-1767

**Dispersion of Longitudinal Waves in a Rectangular Transversely Isotropic Wave-Guide**

P. Muller and M. Touratier
Laboratoire de Mecanique Theorique associe au C.N.R.S., Universite P. et M. Curie, 75230 Paris Cedex 05, France, Wave Motion, 3 (2), pp 181-202 (Apr 1981) 7 figs, 1 table, 21 refs

Key Words: Wave propagation, Wave guide analysis

With the help of the Virtual-Power Method, a one-dimensional model is constructed to examine the propagation of longitudinal waves along a homogeneous transversely isotropic wave guide of rectangular cross section. Complex kinematical effects are taken into account. The ten-mode dispersion curves for this model are displayed and thoroughly discussed. The influence of the kinematical effects of interest is evaluated, and the model is compared with other ones. Agreement with experimental data is also exhibited.

**81-1768**
**The Phenomenon of Homeopathic Instability in Dynamical Systems**
C.D. Johnson
Electrical Engrg. Dept., Univ. of Alabama in Huntsville, Huntsville, AL 35807, Intl. J. Control, 33 (1), pp 159-173 (Jan 1981) 9 refs

Key Words: Stabilization, Dynamic systems

Unstable dynamical systems possessing the special mechanism of instability, which is labeled 'homeopathic instability', have the property that they cannot be stabilized unless one employs a feedback controller which itself is unstable. The fact that system designers must employ unstable controllers to achieve stabilization of certain unstable systems raises some interesting technical and philosophical questions – especially in modern socio-economic applications of control theory where the 'controller' is often a committee or some other form of human operator. The occurrence of homeopathic instability is demonstrated by a family of examples from the class of completely controllable, completely observable time-invariant linearized dynamical systems.

**81-1769**
**The Time of Frictionless Motion of a Swinging Compound Pendulum**
A. Samson
N.S.W. Inst. Tech., Sydney, 2007, Australia, J. Mech. Des., Trans. ASME, 102 (4), pp 818-822 (Oct 1980) 4 figs, 5 refs

Key Words: Pendulums, Equations of motion

The equations of motion of a free swinging compound (physical) pendulum were integrated to obtain a general solution for the elapsed time in the form of a trigonometric integral. The latter was reduced to Jacobian elliptic functions of the first kind, which were then solved by conventional techniques for complete and incomplete integrals. Five specific cases of the time intervals of motion of a compound pendulum were analyzed and solutions obtained.

## MODELING TECHNIQUES
(See No. 1606)

## NONLINEAR ANALYSIS

**81-1770**
**Vibrations, Stability and General Solutions for the Duffing and Other Non Linear Equations**
S. Nocilla
Istituto di Meccanica Razionale, Politecnico di Torino, Italy, Meccanica, 15 (3), pp 131-139 (Sept 1980) 16 figs, 10 refs

Key Words: Nonlinear systems, Single degree of freedom systems, Duffing's differential equation

A general procedure is developed in order to calculate the vibratory motions of non linear systems with one degree of freedom. The vibration is considered as an infinite sequence of increasing and decreasing half-waves, for each of which time and deplacement are considered as initial data, with initial velocity zero. Recurrent formulae giving the initial data for each half-wave as a function of those relative to the preceeding half-wave are calculated. This procedure is applied to the Duffing equation and leads to study of the powers of a matrix, whose behavior, when the exponent goes to infinity, determines the character of stability or instability or asymptotic periodicity of the solution.

## NUMERICAL METHODS

**81-1771**
**Method for Computing Time Response of Systems Described by Transfer Functions**
K. Singhal and J. Vlach
Faculty of Engrg., Univ. Waterloo, Waterloo, Ontario, Canada N2L 3G1, J. Franklin Inst., 311 (2), pp 123-130 (1981) 1 table 4 refs

Key Words: Numerical analysis, Time-dependent parameters, Laplace transformation

A simple numerical method for computing the time domain response of linear time invariant systems described by their transfer functions is presented. The method does not require computation of transfer function poles or residues; it is not influenced by the multiplicity of poles or zeroes, nor does it require computation of the matrix exponential. Rather, it is based on a numerical method for inverting Laplace transforms. It is equivalent to very high order, absolutely stable numerical integration. Stiff systems present no problems.

**81-1772**
**The Solution of Forced Vibration Problems by the Finite Integral Method**
P. Swannell

Dept. Civil Engrg., Queensland Univ., Brisbane, Australia, Rept. No. RR-CE16, 55 pp (Aug 1980)
PB81-136319

Key Words: Integral equations, Numerical analysis, Forced vibration

The finite integral method is a numerical method of solving simultaneous differential equations. This paper reviews the technique and explores the solution of some forced vibration problems.

## PARAMETER IDENTIFICATION

**81-1773**
**Inverse Problems in Structural Dynamics - I. Theory**
S.S. Simonian
J.H. Wiggins Co., Redondo Beach, CA, Intl. J. Numer. Methods Engrg., 17 (3), pp 357-365 (Mar 1981) 37 refs

Key Words: Parameter identification technique, Linear systems, Nonlinear systems, Frequency domain method, Dynamic programming

Theoretical and methodological aspects of inverse problems of system parameter identification are discussed. For conceptual clarity, as well as generality, the joint state and parameter identification problem for dynamical systems, described in terms of a system of first-order nonlinear differential equations, is addressed. This paper also presents the identification problem of linear sytems. For this case, important computational efficiency is achieved by transforming the identification problem into other domains (e.g., frequency domain) and recursively operating the dynamic programming filter in the new domains.

**81-1774**
**Inverse Problems in Structural Dynamics – II. Applications**
S.S. Simonian
J.H. Willins Co., Redondo Beach, CA, Intl. J. Numer. Methods Engrg., 17 (3), pp 367-386 (Mar 1981) 11 figs, 37 refs

Key Words: Parameter identification technique, Dynamic programming, Frequency domain, Monte Carlo method

In this paper the effectiveness of the novel dynamic programming filter is demonstrated for an inverse problem in wind engineering, namely the identification of structure and wind force parameters.

**81-1775**
**Identification of Nonlinear Systems Using Parameter Estimation Techniques**
S.A. Billings and I. Leontaritis
Sheffield Univ., UK, Rept. No. RR-117, 6 pp (Sept 1980)
N81-14779

Key Words: System identification techniques, Parameter identification technique

The identification of nonlinear systems using parameter estimation methods based on input/output difference equation models is considered. A general representation of a wide class of nonlinear systems is derived by considering an observability condition. The Hammuerstein, Wiener, bilinear and other well known models are shown to be special cases of the nonlinear model. The effects of internal noise are investigated and the estimation of the coefficients using linear estimation algorithms is shown to yield biased estimates. A modified extended least squares algorithm is presented and structure detection methods and model validity checks are briefly discussed.

**81-1776**
**A Condition for Maintaining Natural Frequencies of a Vibrating System During Parameter Change (Eine Bedingung zur Erhaltung des Eigenfrequenzspektrums schwingungsfähiger Systeme bei Parameteränderung)**
K.-D. Salewski and U. Marzok
Ernst-Moritz-Arndt-Universität Greifswald, Sektion Physik/Elektronik, Maschinenbautechnik, 30 (2), pp 88-90 (Feb 1981) 1 fig, 4 refs
(In German)

Key Words: Natural frequencies, Mode shapes, Vibrating structures, Parametric resonance

An equation is derived which enables the determination of the parameters of a vibrating system, so that they do not affect the natural frequencies of the system. The equation is based on similarity transformation of matrices.

**81-1777**

**System Identification in Earthquake Engineering**

J.T.P. Yao and A.J. Schiff

School of Civil Engrg., Purdue Univ., Lafayette, IN, Rept. No. CE-STR-80-7, NSF/RA-800205, 16 pp (May 1980)

PB81-140667

Key Words: System identification techniques, Earthquake resistant structures, Seismic design

Application of system identification techniques in earthquake engineering research is described with emphasis on the damage evaluation of existing structures. The report considers use of identification in the following situations involving existing structures: analysis of dynamic test data; analysis of strong-motion earthquake response data; and analysis of post-earthquake data. Problems common to each of these applications are reviewed. An approach to resolve the uncertainty problem in analysis is suggested.

## MOBILITY/IMPEDANCE METHODS

(See No. 1729)

## OPTIMIZATION TECHNIQUES

(See No. 1764)

## DESIGN TECHNIQUES

(Also see No. 1777)

**81-1778**

**Design Sensitivity in Dynamical Systems**

J.E. Whitesell

Michigan State Univ., Ph.D. Thesis, 106 pp (1980)

UM 8106459

Key Words: Modal analysis, Taylor series, Design techniques

Modal analysis is a standard tool used in the design of dynamical systems. By numerically determining certain eigenvalues and eigenvectors associated with a linear structural model, its vibratory behavior can be investigated. The difficulty with this technique is that it may be costly in computer time if several redesigns (and re-evaluations of the eigenvalues and eigenvectors) are needed to find a suitable design. The thesis presents a technique to represent selected eigenvalues and eigenvectors by a Taylor series in a design variable. Since, with the technique, the Taylor coefficients can be computed efficiently and to arbitrary order, the Taylor series can be used to accurately estimate the consequences of a design change. The technique, therefore, has the potential to substantially reduce the number of calculations necessary to re-evaluate the eigensystem after a design change.

## COMPUTER PROGRAMS

(Also see No. 1632)

**81-1779**

**Soil-Structure Interaction Methods: Summary Report**

C.A. Miller

Brookhaven National Lab., Upton, NY, Rept. No. BNL-NUREG-51263-Vol-1, 22 pp (Dec 1980)

NUREG/CR-1717-V-1

Key Words: Computer programs, Interaction: soil-structures, Seismic analysis

The objective of the work reported here was to implement three computer programs on the Brookhaven National Laboratory (BNL) CDC 7600 computer system. The three programs are centered about the soil-structure interaction problem in seismic analyses. In this volume the capabilities of each of the codes are discussed following a general overview of the seismic analysis problem indicating how the codes fit into the total problem.

# GENERAL TOPICS

## CONFERENCE PROCEEDINGS

**81-1780**

**INTERNOISE 80. NOISE CONTROL IN THE 80's.**

Proc. Intl. Conf. Noise Control Engrg., Miami, FL, Dec 8-10, 1980, 2 vols

Key Words: Vibration control, Noise reduction, Proceedings

The 250 papers presented at this Conference are grouped into ten sections dealing with: long range plans for the identification and control of environmental noise; general topics of noise control; noise generating devices of all kinds; sound propagation; noise barriers, silencers and materials;

vibration generation, transmission, isolation and reduction; building and community noise control; hearing and psychological effects of noise; instrumentation systems, measurement techniques, test facilities, analytical methods and modeling; and standards associated with Federal, State, and local legislation. Abstracts of individual papers are listed in the appropriate sections of this issue of the Digest.

**81-1781**
**Vibration Techniques**
Nederlands Akoestisch Genootschap, Delft, Publ-51, 47 pp (Jan 1980)
N81-15399

Key Words: Vibration measurement, Measurement techniques

Various approaches for the solution of mechanical vibration and noise problems are reported. Abstracts of individual articles are listed in the appropriate sections of the Digest.

## TUTORIALS AND REVIEWS

**81-1782**
**Response of Nonlinear Mechanical Systems to Random Excitation. Part I: Markov Methods**
J.B. Roberts
School Engrg. and Appl. Sciences, Univ. Sussex, Falmer, Brighton, Sussex, UK, BN1 9QT, Shock Vib. Dig., 13 (4), pp 17-28 (Apr 1981) 107 refs

Key Words: Reviews, Nonlinear systems, Random excitation

Part I of two-part survey outlines recent progress in applying the theory of Markov processes, in particular the Fokker-Planck-Kolmogorov equation, to the problem of predicting the response of nonlinear systems to random excitation. A variety of approximate methods of solution are discussed; emphasis is on applications.

**81-1783**
**Vibration of Curved Beams**
Š. Markuš and T. Nánási
Inst. Matls. and Machine Mechanics, Slovak Academy Sciences, Dubravska cesta 809 31 Bratislava, Czechoslovakia, Shock Vib. Dig., 13 (4), pp 3-14 (Apr 1981) 193 refs

Key Words: Reviews, Beams, Curved beams

Because they are important in many practical applications, free vibrations of curved beams in their own plane or out-of-plane have been the subject of numerous investigations. This paper reviews various methods for analyzing the effects of curvature in connection with other complicating phenomena. These phenomena include rotatory inertia, shear deformation, extension of the central line, dislocations of the central and neutral axes, distribution of the stress along the cross section, damping, and boundary conditions. The influence of these phenomena on the mechanics of vibration of curved beams is also considered.

**81-1784**
**Noise and Noise Abatement in Fans and Blowers: A Review**
W. Neise
Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt e.V., Goettingen, F.R. Germany, Rept. No. DFVLR-FB-80-16
N81-14796
(In German; English summary)

Key Words: Reviews, Fans, Blowers, Noise reduction

Noise generation and its reduction industrial fans (ventilators) is addressed. A review is given of the fan types commonly in use and their practical applications, the mechanisms of the aerodynamic noise generation in fans, theoretical and empirical prediction methods for fan noise, acoustic similarity laws, and noise reduction methods by means of the fan construction and fan operation. Measurement procedures are discussed with respect to the noise radiated from different parts of a fan, e.g., from the fan inlet or outlet, from the fan casing, from the fan as a whole, and to the noise radiated into ducts connected to the fan. Finally, considerations are made, for which classes of fans noise standards can be defined to characterize the noise emission of the various types.

**81-1785**
**A Review of the Response of Buried Pipelines under Seismic Excitations**
T. Ariman

College of Engrg. and Physical Sciences, Univ. Tulsa, Tulsa, OK, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (2), pp 133-151 (Mar-Apr 1981) 9 figs, 3 tables, 109 refs

Key Words: Underground structures, Pipelines, Life line systems, Seismic response, Interaction: soil-structures, Reviews

An updated and detailed review of the earthquake response and seismic-resistant design of underground piping systems is presented.

**81-1786**
**Activities of the Institute of Sound and Vibration Research for the Year Ending March 1980**
Inst. Sound Vib. Res., Southampton Univ., Southampton, UK, Annual Report Period ending Mar 1980, 51 pp (1980)
N81-14960

Key Words: Test facilities, Noise reduction, Vibration control, Computer programs

Research in fluid dynamics, automotive engineering, structural dynamics, and electronics is summarized and its role in acoustics is discussed. A review of industrial noise and vibration control is presented. Data analysis and a compendium of computer programs are presented.

## BIBLIOGRAPHIES

**81-1787**
**Vibrational Analysis in Fluids. January, 1970 - November, 1980 (Citations from the NTIS Data Base)**
J.E. Wroblewski
New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACUSGNT2311, 92 pp (Nov 1980)
PB81-853673

Key Words: Bibliographies, Fluid-induced excitation, Vibration response, Fatigue life

The bibliography presents an analysis of vibrational, fatigue, stress and mechanical responses of fluids through a range of applications. The report discusses general areas of shapes and mechanisms working within and/or in conjunction with fluids. The general information is experimental in nature and could transfer to numerous fields. Specific data and procedures include applications in aerodynamics, hydrodynamics, hydraulics, and nuclear reactor technology.

**81-1788**
**Vibrational Analysis in Fluids. January, 1970 - November, 1980 (Citations from the Engineering Index Data Base)**
J.E. Wroblewski
New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACEI NT 2311, 120 pp (Nov 1980)
PB81-853681

Key Words: Bibliographies, Fluid-induced excitation, Vibration response, Fatigue life

This bibliography presents an analysis of vibrational, fatigue, stress and mechanical responses of fluids through a range of applications. The report discusses general areas of shapes and mechanisms working within and/or in conjunction with fluids. The general information is experimental in nature and could transfer to numerous fields. Specific data and procedures include applications in mechanical engineering, hydrodynamics, hydraulics and nuclear reactor technology.

**81-1789**
**Dynamic Structural Vibration Analysis with the Computer. January, 1972 - December, 1980 (Citations from the International Aerospace Abstracts Data Base)**
New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACIAANT2496, 137 pp (Dec 1980)
PB81-855900

Key Words: Bibliographies, Vibration analysis, Design techniques, Elasticity, Optimization, Mathematical models, Computer programs

This retrospective bibliography contains structural engineering analyses of various shapes and bodies. It presents various problems confronting engineers in the fields of design, elasticity, and structural limitations, along with the use of computer technology to provide solutions and optimization. The report presents mathematical models and cites specific computer programs and techniques.

**81-1790**

**Vibrational Analysis in Aerodynamics. January, 1970 - November, 1980 (Citations from the NTIS Data Base)**

New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACUSGNT 2263, 161 pp (Nov 1980)
PB81-853921

Key Words: Bibliographies, Aerodynamic loads, Panels, Flutter, Vortex shedding

This bibliography contains citations concerning both the design and performance areas of applied aerodynamics. The reports cover classical flutter, stall flutter, panel flutter, vortex shedding, weight estimation, buffeting and flow-induced oscillations. The general thrust of the information is toward computer solutions of mathematical problems. It also covers some blade related areas as well as the aerospace field.

**81-1791**

**Vibrational Analysis in Aerodynamics. January, 1970 - November, 1980 (Citations from the Engineering Index Data Base)**

New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACEI NT 2263, 81 pp (Nov 1980)
PB81-853939

Key Words: Bibliographies, Aerodynamic loads, Panels, Flutter, Vortex shedding

This bibliography contains citations concerning both the design and performance areas of applied aerodynamics. The reports cover classical flutter, stall flutter, panel flutter, vortex shedding, galloping, wake galloping, buffeting and flow-induced oscillations. The general thrust of the information is toward computer solutions of mathematical problems. It also covers some blade related areas as well as the aerospace field.

**81-1792**

**Vibrational Analysis in Aerodynamics. January, 1972 - November, 1980 (Citations from the International Aerospace Abstracts Data Base)**

New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACIAANT 2263, 125 pp (Nov 1980)
PB81-853947

Key Words: Bibliographies, Aerodynamic loads, Panels, Flutter, Vortex shedding

This bibliography contains citations concerning both the design and performance areas of applied aerodynamics. The reports cover classical flutter, stall flutter, panel flutter, vortex shedding, weight estimation, buffeting and flow-induced oscillations. The general thrust of the information is toward computer solutions of mathematical problems. It also covers some blade related areas as well as the aerospace field.

**81-1793**

**Computer Analysis for Equations of Motion in Flight. January, 1972 - December, 1980 (Citations from the International Aerospace Abstracts Data Base)**

J.E. Wroblewski

New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACIAANT2246, 123 pp (Dec 1980)
PB81-854291

Key Words: Bibliographies, Aircraft, Equations of motion, Computer aided techniques

This retrospective bibliography contains citations concerning mathematical procedures explaining the nature of objects in motion. The report presents a variety of examples and experiments and includes spin performance of aircraft, airframe flutter and dynamic structural analysis, aircraft performance, accident analysis, flight simulation, missile and weapons data, and spacecraft. The solutions presented slant toward computer optimizations and techniques documenting both anclog and digital modeling. They often refer to specific software programs.

**81-1794**

**Computer Analysis for Equations of Motion in Flight. January, 1970 - December, 1980 (Citations from the NTIS Data Base)**

J.E. Wroblewski

New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACUSGNT2246, 197 pp (Dec 1980)
PB81-854283

Key Words: Bibliographies, Aircraft, Equations of motion, Computer aided techniques

This retrospective bibliography contains citations concerning mathematical procedures explaining the nature of objects in

motion. The report presents a variety of examples and experiments and includes spin performance of aircraft, airframe flutter and dynamic structural analysis, aircraft performance, accident analysis, flight simulation, missile and weapons data, and spacecraft. The solutions presented slant toward computer optimizations and techniques documenting both analog and digital modeling. They often refer to specific software programs.

**81-1795**

**Mechanical Vibration Problems with Fluids. January, 1972 - December, 1980 (Citations from the International Aerospace Abstr' cts Data Base)**

New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACIAANT 2483, 61 pp (Dec 1980)
PB81-855041

Key Words: Bibliographies, Fluid-induced excitation, Vibration response, Fatigue life

This bibliography presents an analysis of vibrational, fatigue, stress and mechanical responses of fluids through a range of applications. The report discusses general areas of shapes and mechanisms working within and/or in conjunction with fluids. The general information is experimental in nature and could transfer to numerous fields. Specific data and procedures include applications in structural mechanics, aerodynamics, hydrodynamics and hydraulics.

**18-1796**

**Nondestructive Testing of Pipes and Tubes. January, 1976 - July, 1980 (Citations from the Energy Data Base)**

J.H. Frey
New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACEDBNT1146, 154 pp (Aug 1980)
PB81-851479

Key Words: Bibliographies, Pipes (tubes), Tubes, Nondestructive tests

This retrospective bibliography contains citations concerning the nondestructive techniques for testing or examining a wide variety of pipes and tubes for the detection of flaws or defects which affect their mechanical properties.

**81-1797**

**Nondestructive Testing of Pipes and Tubes. January, 1970 - July, 1980 (Citations from the Engineering Index Data Base)**

J.H. Frey
New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACEI NT1146, 97 pp (Aug 1980)
PB81-851487

Key Words: Bibliographies, Pipes (tubes), Tubes, Nondestructive tests

This retrospective bibliography contains citations concerning the nondestructive techniques for testing or examining a wide variety of pipes and tubes for the detection of flaws or defects which affect their mechanical properties.

**81-1798**

**Nondestructive Testing of Pipes and Tubes. January, 1970 - July, 1980 (Citations from the NTIS Data Base)**

J.H. Frey
New England Res. Applic. Ctr., Storrs, CT, Rept. No. NERACUSGNT1146, 93 pp (Aug 1980)
PB81-851461

Key Words: Bibliographies, Pipes (tubes), Tubes, Nondestructive tests

This retrospective bibliography contains citations concerning the nondestructive techniques for testing or examining a wide variety of pipes and tubes for the detection of flaws or defects which affect their mechanical propert'.s.

## USEFUL APPLICATIONS

**81-1799**

**Dimensional Measurement by Microwave Resonances**

J.C. Gallop and W.J. Radcliffe
Div. Quantum Metrology, Natl. Physical Lab., Queens Rd., Teddington, Middlesex TW11 OLW, UK, J. Phys. E. (Sci. Instr.), 14, pp 461-463 (Apr 1981) 4 figs, 5 refs

Key Words: Dimensional measurement, Tubes, Resonant frequencies

A method is demonstrated for measuring small departures from true cylindricity of a tube by using it as a microwave cavity and then applying a perturbation method to the observed resonant frequencies. The technique is also applicable to other geometries.

# AUTHOR INDEX

# CALENDAR

## SEPTEMBER 1981

1-4 Joint Meeting of the British Society for Strain Measurement and the Society for Experimental Stress Analysis [B.S.S.M. and SESA] Edinburgh University, Scotland *(C. McCalvey, Administration Officer, B.S.S.M., 281 Heaton Road, Newcastle upon Tyne, NE6 5OB, UK)*

7-11 Applied Modelling and Simulation Conference and Exhibition [I.A.S.T.E.D. and A.M.S.E.] Lyon, France *(A.M.S.E., 16, Avenue de Grande Blanche, 69160 Tassin-La-Demi-Lune, France)*

14-17 International Off-Highway Meeting and Exposition [SAE] Milwaukee, WI *(SAE Hqs.)*

20-23 Design Engineering Technical Conference [ASME] Hartford CT *(ASME Hqs.)*

28-30 Specialists Meeting on "Dynamic Environmental Qualification Techniques" [AGARD Structures and Materials Panel] Noordwijkerhout, The Netherlands *(Dr. James J. Olsen, Structures and Dynamics Division, Air Force Wright Aeronautical Laboratories/FIB, Wright Patterson Air Force Base, OH 45433)*

28-30 Stapp Car Crash Conference [SAE] San Francisco, CA *(SAE Hqs.)*

30-Oct 2 International Congress on Recent Developments in Acoustic Intensity Measurement [CETIM] Senlis, France *(Dr. M. Bockhoff, Centre Technique des Industries Mecaniques, Boite Postale 67, F-60304, Senlis, France)*

## OCTOBER 1981

4-7 International Lubrication Conference [ASME - ASLE] New Orleans, LA *(ASME Hqs.)*

5-8 SAE Aerospace Congress and Exposition [SAE] Anaheim, CA *(Roy W. Mustain, Rockwell Space Systems Group, AB 97, 12214 S. Lakewood Blvd., Downey, CA 90241)*

11-15 Fall Meeting of the Society for Experimental Stress Analysis [SESA] Keystone, CO *(SESA, P.O. Box 277, Saugatuck Station, Westport, CT 06880)*

19-22 Intl. Optimum Structural Design Symp. [U.S. Office of Naval Research and Univ. of Arizona] Tucson, AZ *(Dr. Erdal Atrek, Dept. of Civil Engr., Bldg. No. 72, Univ. of Arizona, Tucson, AZ 85721)*

21-23 34th Mechanical Failures Prevention Group Symp. [National Bureau of Standards] Gaithersburg, MD *(J.E. Stern, Trident Engineering Associates, 1507 Amherst Rd., Hyattsville, MD 20783 - (301) 422-9506)*

26-30 ASCE Annual Convention & Exposition [ASCE] St. Louis, MO *(ASCE Hqs.)*

27-29 52nd Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, D.C.] New Orleans, Louisiana *(Henry C. Pusey, Director, SVIC, Naval Research Lab., Code 5804, Washington, D.C. 20375)*

## NOVEMBER 1981

9-12 Truck Meeting & Exposition [SAE] Dearborn, MI *(SAE Hqs.)*

15-20 ASME Winter Annual Meeting [ASME] Washington, D.C. *(ASME Hqs.)*

16-19 International Pacific Conference on Automotive Engineering [SAE] Honolulu, Hawaii *(SAE Hqs.)*

17-19 Technical Diagnostics Symposium [IMEKO Technical Committee on Technical Diagnostics] London, England *(Institute of Measurement and Control, 20 Peel Street, London W8 7PD, England)*

18-20 Fourth SAE International Conference on Vehicle Structural Mechanics [SAE] Detroit, MI *(SAE Hqs.)*

30-Dec 4 Acoustical Society of America, Fall Meeting [ASA] Miami Beach, FL *(ASA Hqs.)*

## DECEMBER 1981

1-3 10th Turbomachinery Symposium [Texas A&M University] Houston, TX *(Peter E. Jenkins, Director, Turbomachinery Laboratories, Dept. of Mechanical Engineering, Texas A&M University, College Station, TX 77843 - (713) 845-7417)*

1-3 Automotive Plastics Durability Conference and Exposition [SAE] Troy, MI *(SAE Hqs.)*

8-10 Western Design Engineering Show [ASME] Anaheim, CA *(ASME Hqs.)*

## CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - U.S. National Committee
c/o MIT Lincoln Lab.
Lexington, MA 02173